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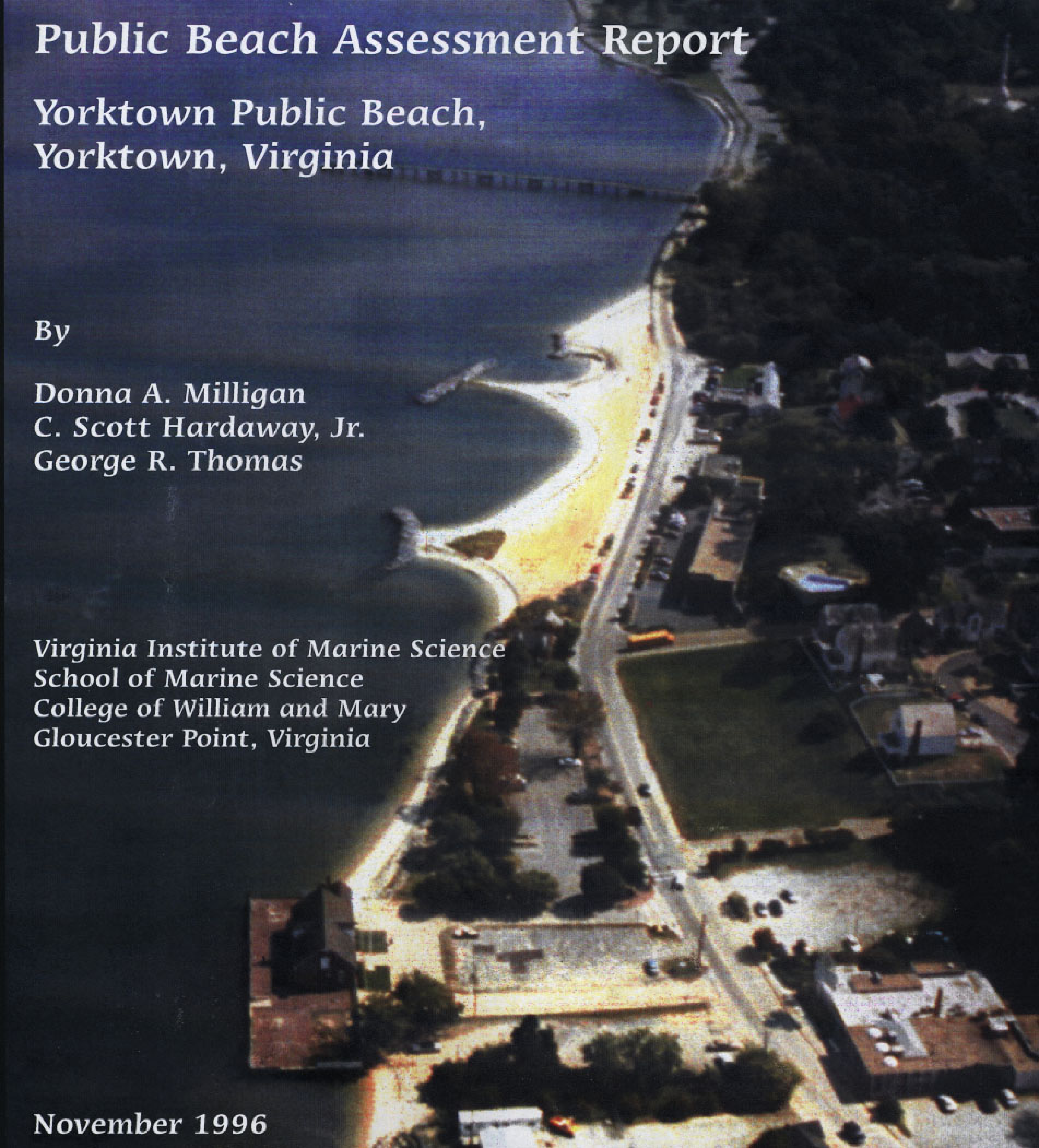

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Contract with
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EXECUTIVE SUMMARY

Yorktown Public Beach is located on the south side of the York River in Yorktown, Virginia. It is part of a larger stretch of shoreline form the U.S. Post Office near the Coleman Bridge to Point of Rocks in the Colonial National Historical Park. In general, the shoreline is low but backed by high bluffs. Erosion of these bluffs over time has supplied material for the beaches along the York River. With hardening of the updrift shorelines, Yorktown Public Beach began to narrow and was easily overwashed in storms, flooding Water Street and jeopardizing the commercial establishments near the waterfront.

Several coastal projects have taken place at Yorktown. A stone revetment was constructed along the shoreline in 1978. In 1986, a small breakwater was built to protect the storm sewer outfall pipe, and the beach was nourished with 10,000 cubic yards of sand. As erosive wave action continued to remove sand, the beach was replenished in 1989. However, a more permanent solution to the chronic erosion at Yorktown was needed. In 1994, York County installed an offshore breakwater system at the Public Beach. In addition, 11,000 cubic yards of sand was placed on the beach, and marsh grasses were planted in the lee of the structures.

The purpose of this report is to assess the rates and patterns of change at the public beach as well as to assess the performance of the 1994 Yorktown Waterfront Shoreline Erosion Control project. Field survey data, aerial photos, wave climate analysis and computer modeling were analyzed for this report. RCPWAVE, a wave hydrodynamic model developed by the US Army Corps of Engineers and modified at VIMS, was used to model wave patterns.

In general, sand moves from east to west along the Yorktown shoreline. However, during northwest storms, there can be a reverse in the littoral transport system. The net long-term change along the public beach shoreline was erosion until the installation of the breakwaters. Now the shoreline between the bathhouse and Comte de Grasse Street has been stabilized. However, because this shoreline is so low, overwash during storms is common. Even though the shoreline between the U.S. Post Office and the bathhouse is occasionally supplied sand by littoral drift during northwest storms, it has a severe erosion problem now that the sand that once supplied this stretch of shoreline is locked up by the breakwaters.

Phase II of York County's shoreline plan for Yorktown is currently in the design stage. It should address erosion problems along the stretch of shoreline between the U.S. Post Office and the bathhouse. We also recommend raising the backshore region of the beach seaward of the sidewalk in order to stop flooding of Water Street.

ACKNOWLEDGMENTS

We would like to thank Jerome P. -Y. Maa for his assistance with the modeling effort. Also, thanks to Dan Hepworth for his effort in hindcasting the wave climate and Kea Duckenfield for making our figures presentable. Finally, thanks to Neville Reynolds of VHB with whom we worked closely on the 1994 project at Yorktown and who supplied us with information for this report.

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I. INTRODUCTION

A. Background and Purpose

The Yorktown Public Beach is located on the south side of the York River within the community of Yorktown, VA (Figure 1). The public beach extends from the U.S. Post Office southeast for about 1900 feet (579 m) to the Colonial National Historical Park (CNHP), but only the first 1350 feet (411 m) are considered a recreational beach. Anderson *et al.* (1975) list an historic shoreline erosion rate rangeing between 0.7 ft per year (ft/yr) and 1.6 ft/yr for the stretch of shoreline from the Coleman Bridge to Goodwin Neck. Byrne and Anderson (1978) specify 1.6 ft/yr for the Public Beach and the Colonial National Historical Park. A wide beach existed at Yorktown until the mid 1970's. Over the years, the beaches along the waterfront began to narrow as the natural sediment supply was depleted by hardening of the updrift shorelines with structures, and the beaches were easily overwashed in storms and had continually eroded. As a result of severe erosion, a stone revetment was constructed from the beach to the bath house area in April 1978.

The Yorktown Public Beach is set within a longer reach that extends from the Coleman Bridge eastward to a shore point just downriver of the picnic area on CNHP property. The net movement of beach sands in this reach is from east to west in response to the predominate northeast exposure. Beach sands were historically supplied by erosion of the upland banks adjacent to the CNHP picnic area. However, this area was hardened by a stone revetment in 1983 following the October 26, 1982 northeaster, thus cutting off the last major natural supply of sand to the reach.

On November 4 and 5, 1985, a severe storm removed a large amount of sand from the public beach and also destroyed the sidewalk along the backshore (Figure 2A and 2B). A new revetment and side walk was subsequently built in early 1986, utilizing the emergency fund from the Public Beach Board. Beach fill was added, and a small stone breakwater was installed that served to stabilize the storm drain at Comte de Grasse street as well as help set the eastern edge of the beach fill (Figure 2C). The stone seawall along Water Street was also repaired at this time.

Since the 1986 project, the beach has suffered chronic erosion, and the stone revetment was intermittently exposed (Figure 2D). A small beach nourishment project was performed in 1989, but this material was soon lost to erosive wave action. By 1994, the stone revetment was constantly exposed for a distance of about 300 feet upriver of the small breakwater (Figure 3A). This condition resulted in the development of plans to emplace additional breakwaters and beach fill.

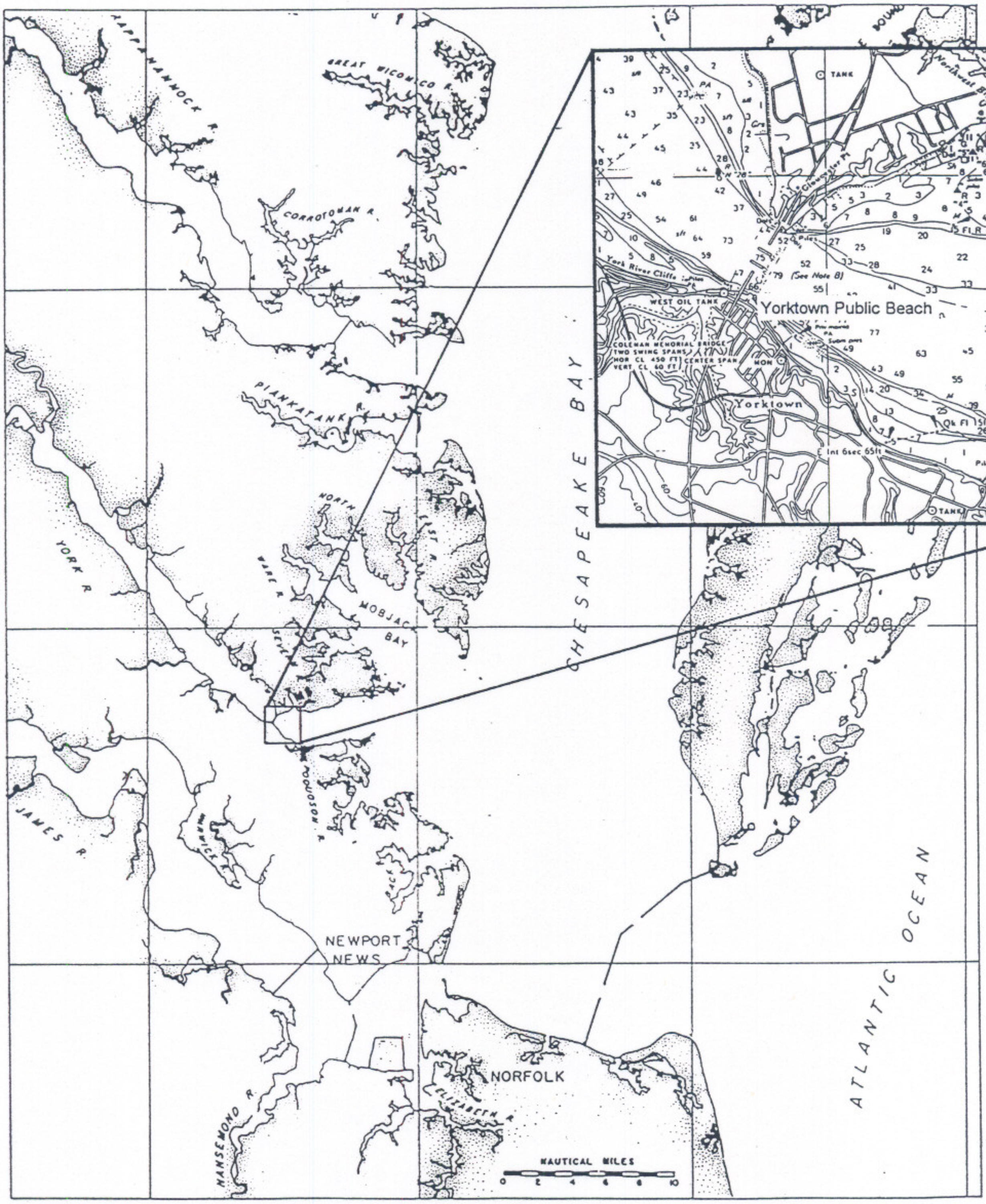


Figure 1. Study site location.

Figure 2A. 4 November 1985. Nor'easter.

Figure 2B. 5 November 1985. Post-storm.

Figure 2C. 15 July 1986. Post-shore construction.

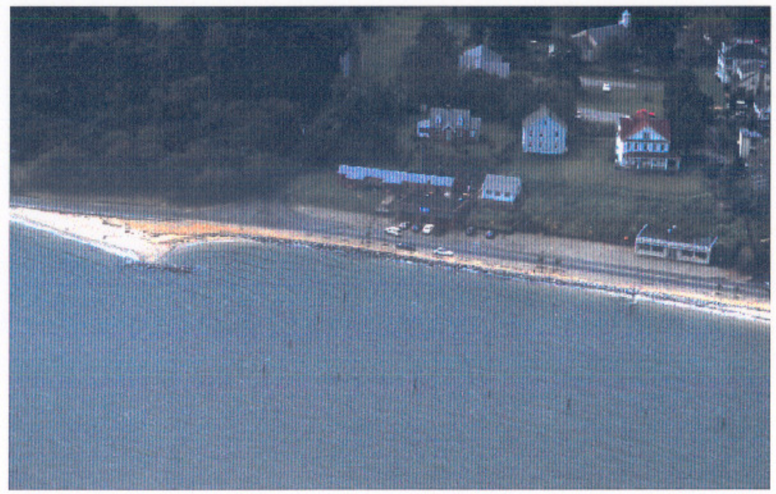


Figure 2D. 20 September 1989. Loss of beach and exposed revetment.

Figure 3A. 4 March 1993. Critical beach loss.

Figure 3B. 2 October 1995. One year after 1994 shore project installation.

Figure 3C. 6 September 1996. Hurricane Fran. Minor Water Street flooding.

Figure 3D. 6 September 1996. Primary breakwater under wave attack.

In September 1994, York County installed a breakwater system consisting of two shore-attached breakwaters, 140 and 120 feet (43 and 37 m) in length, coupled with 7,500 cubic yards (cy) (5740 m^3) of beach fill and plantings of *Spartina alterniflora* and *S. patens* in the lee of the structures (Figure 3B). The pre-existing small breakwater was modified to interface with the system on the downstream end; the 120 foot (37 m) upstream breakwater was designed with a falling crest elevation to encourage wave refraction; and a winged breakwater was designed to achieve a reasonable interface with the adjacent shore and reduce potential wave force impacts during northeasters.

The $260,000 project was funded by the County of York, the Virginia Department of Transportation, and the Virginia Board on Conservation of Public Beaches. In May 1996, approximately 600 cy (460 m^3) of sand was dredged from under the Coleman Bridge in order to facilitate the bridge widening project and was placed on Yorktown Beach. The Yorktown Beach project has weathered numerous storms including Hurricane Fran (Figure 3C and 3D) and, except for unavoidable flooding of Water Street, has remained very much intact.

The purpose of this report is to assess the rates and patterns of beach change at Yorktown Public Beach in Yorktown, Virginia. In addition, those changes will be related to the hydrodynamic forces and littoral processes operating in the study area. Performance of the 1994 Yorktown Waterfront Shoreline Erosion Control project is also evaluated.

B. Limits of the Study Area

The area of detailed analyses were confined to the 1350 feet (411 m) known as the Yorktown Public Beach. However, an analysis of the entire reach from the Coleman Bridge to Point of Rocks in the Colonial National Historical Park was required to ascertain the littoral processes acting on the reach.

C. Approach and Methodology

Field survey data, aerial photos and computer modeling were used to address the studies objectives. Data analyzed for this report include profiles and sediment samples. The vertical datum is mean low water (MLW). Historic and recent aerial images were evaluated to map changes in shoreline positions.

VIMS began monitoring the beach at Yorktown in the spring of 1985. However, a late fall storm in 1985 washed out much of the beach and VIMS's benchmarks. The baseline was reset in 1986 and slightly altered in September 1993. Data from 1986 and later were adjusted to reflect changes to the baseline and datum so that older data could be compared to recent data. In September 1994 two additional profile lines were added, 6.5 and 8.5 (Figure 4).

Figure 5 gives a pictorial definition of the profile terminology used in this report. Nearshore volume calculations take into account all the sand below MLW to the end of each profile. The subaerial beach occurs above MLW and is divided into the beach face (foreshore) and backshore regions.

The hydrodynamic forces acting along the Yorktown shore reach were evaluated using RCPWAVE, a computer model developed by the U.S. Army Corps of Engineers (Ebersole *et al.*, 1986). RCPWAVE is a linear wave propagation model designed for engineering applications. This model computes changes in wave characteristics that result naturally from refraction, shoaling, and diffraction over complex shoreface topography. To this fundamental linear-theory based model, oceanographers at VIMS have added routines which employ recently developed understandings of wave bottom boundary layers to estimate wave energy dissipation due to bottom friction. The reader is referred to Ebersole *et al.* (1986) and Wright *et al.* (1987) for a thorough discussion of RCPWAVE, its use, and theory.

The model was run using modal and storm incident wave conditions (wave height, period, and direction) which were determined following procedures outlined by the U.S. Army Corps of Engineers' Shore Protection Manual (1977 and 1984). These procedures are based on wind/wave hindcast methods across fetch-limited water bodies which were developed by Sverdrup and Monk (1947) and revised by Bretshneider (1952, 1958). The SMB model used in this study was further modified by Kiley (1982) and is essentially a shallow water, estuarine, wind-wave prediction model. Wind data, obtained from Virginia Power's Yorktown Station, which is 2.5 nm (4.6 km) southeast of Yorktown Beach, were used to develop the incident wave conditions for input to the RCPWAVE program.

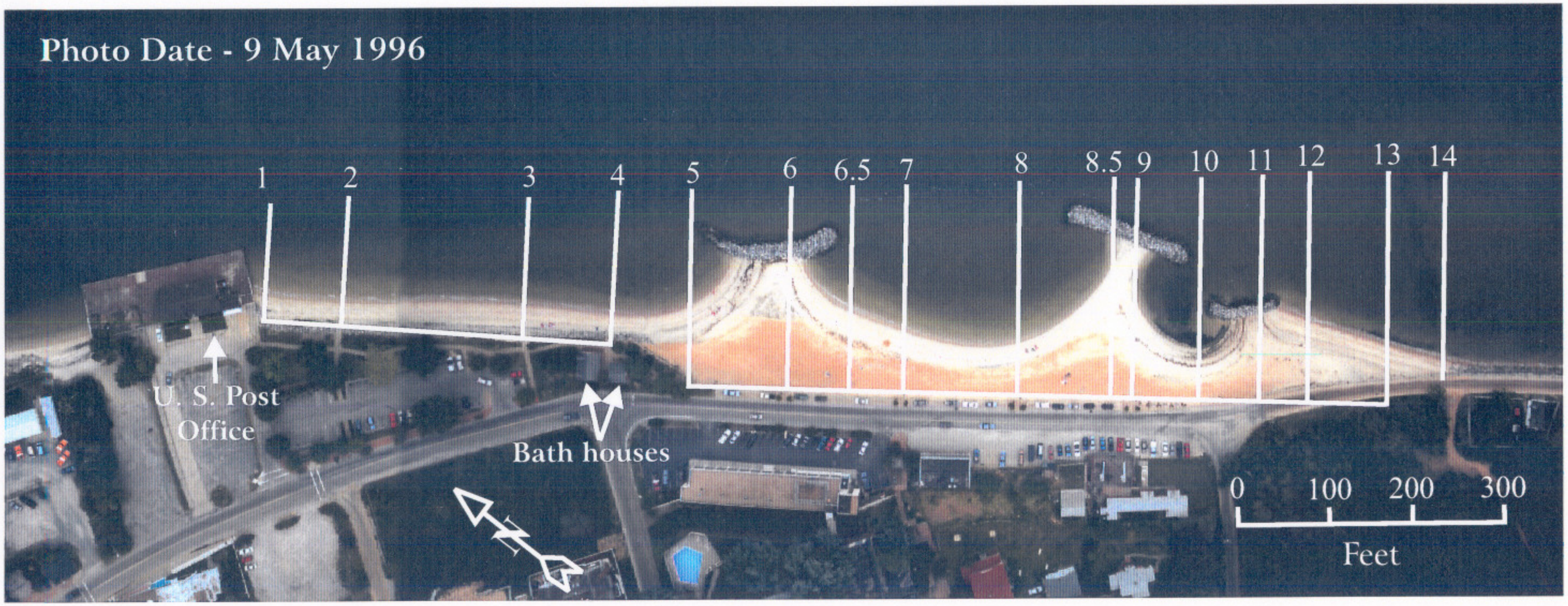


Figure 4. Basemap of Yorktown Beach with profile locations.

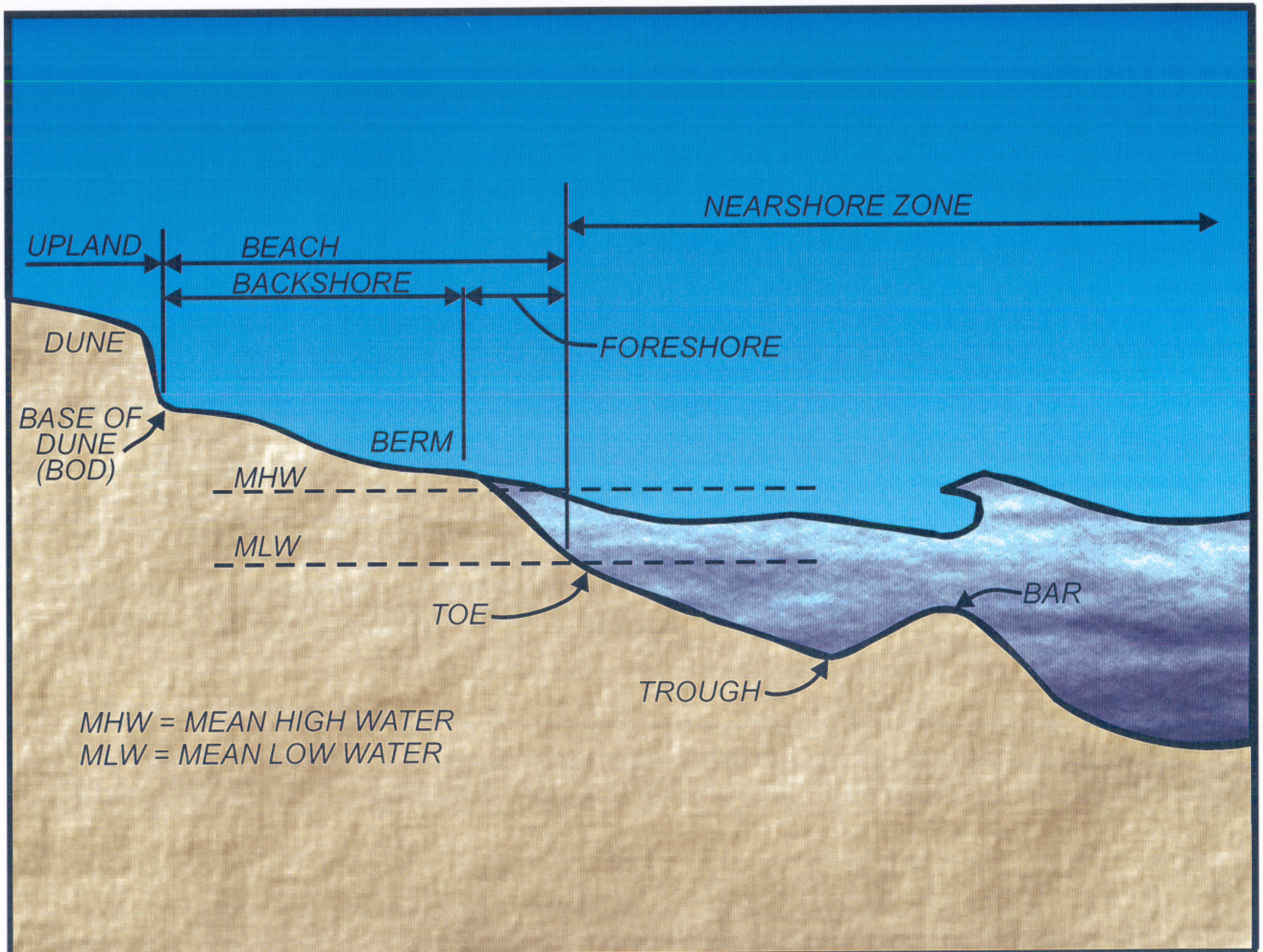


Figure 5. Beach profile demonstrating terminology used in report.

II. COASTAL SETTING

A. Hydrodynamic Processes

1. Wave Climate

The wave climate at Yorktown is affected by both local and bay-generated waves, storm surge, nearshore bathymetry and tidal currents. Local waves are generated by wind events. Fetch and wind speed are primary factors affecting wave height, and because of its location and orientation, the dominant wave conditions at Yorktown shoreline would be associated with winds blowing from the northwest, north, northeast and east. Effective fetches at Yorktown are 3.8 miles (NW), 2.4 miles (N), 3.7 miles (NE) and 6.9 miles (E).

The local wind driven waves play an important role in littoral processes at Yorktown. However, there is a bay component of the wave climate that occurs during northeasters that provide even larger waves coming up the York River. The Chesapeake Bay wave climate was characterized by Goldsmith (1974) who used a linear wave theory based refraction analysis. Figure 6 is an example of northeast and northerly wind driven wave orthogonals using a wind speed of 25 knots (13 m/s). Of note are the wave vectors that reach the mouth of the York River. The wave vectors essentially refract into and proceed up the river. The fetch limited river wave interacts with the longer period bay wave, and the result is an incident wave off Yorktown bearing between 260° and 270° true north (TN).

The wave heights associated with the bay waves generated during "typical" northeasters are on the order of 1.0 to 1.5 meters with a period of 4.5 to 6.0 seconds. Wave data from the VIMS wave deployment at Wolftrap (Boon *et al.*, 1992) captured a storm event in December 7 -10, 1989 with significant wave heights of 1.3 m with wave periods in excess of 5 seconds traveling south southwest down the bay. This wave will refract at the mouth of the York River, travel upriver and reach an offshore position at Yorktown with little attenuation due the relatively deep channel.

The nearshore region is also influenced by the York River channel that runs close to the shoreline. The average distance to the 60 foot (18 m) contour from Yorktown beach is 500 feet (152 m); near the U.S. Post Office, the channel comes close to the shoreline. The York River channel experiences heavy use by commercial and military ships whose wake minimally affect the wave climate at Yorktown. Section III provides more detail of the local wave climate through hydrodynamic modeling.

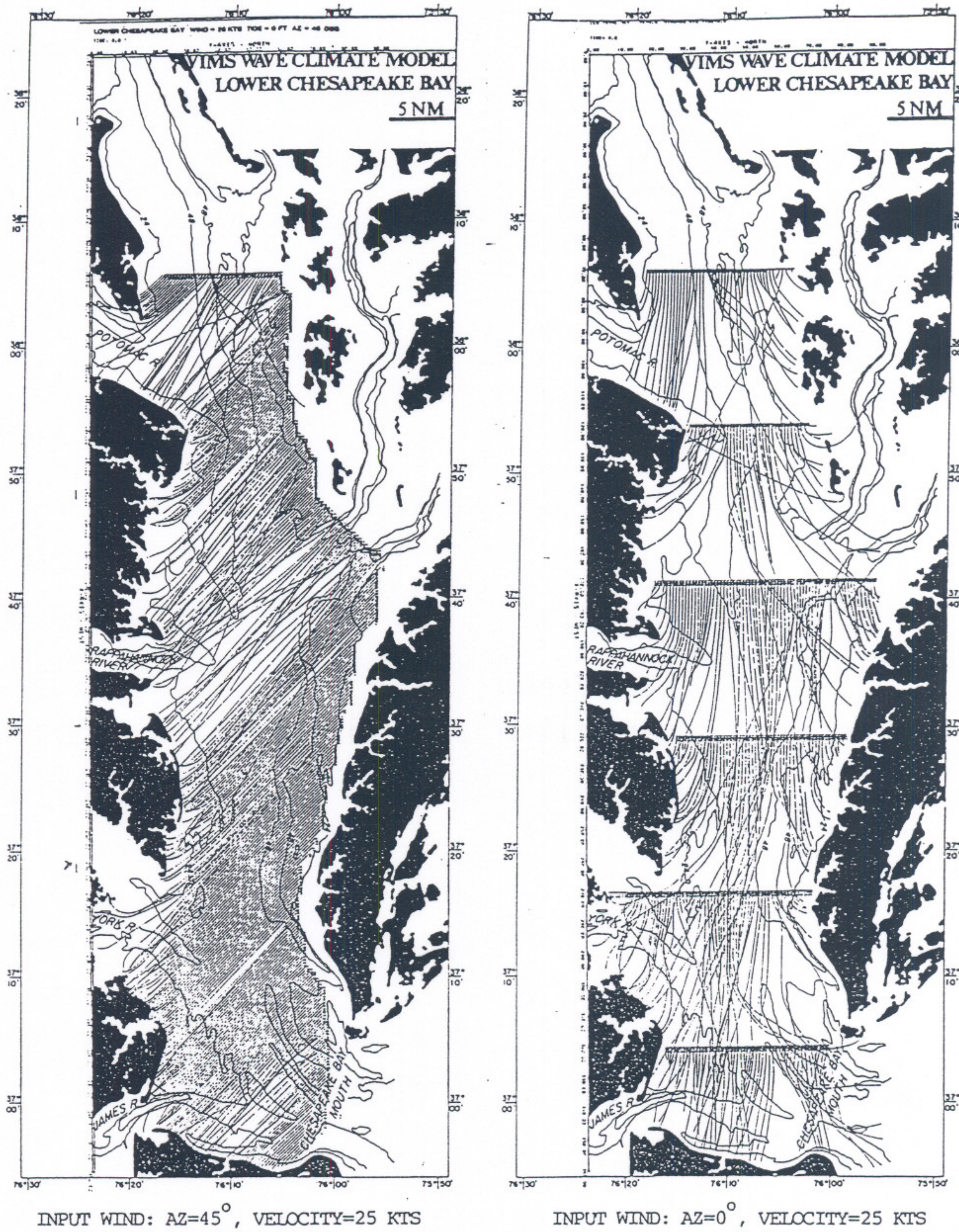


Figure 6. Refraction of Bay-generated waves (after Rosen, 1976).

2. Tides

The mean tidal range at Yorktown Beach is 2.4 ft (73 cm) with a spring range of 2.9 ft (88 cm) (Tidelog, 1996).

3. Storm Surge

Boon *et al.* (1978) statistically determined storm surge frequency for both extratropical and tropical storm events. In the Yorktown area, the storm surge levels for 10 year, 50 year, and 100 year events are 5.8 ft (1.8 m), 6.6 ft (2.0 m), and 7.1 ft (2.2 m), respectively. These surge levels are heights above MLW. However, the Corps of Engineers (U.S. Army Corps of Engineers, 1993) reported higher values for the same storm frequencies. These storm surge levels for 10 year, 50 year, and 100 year events are 7.6 ft (2.3 m), 9.0 ft (2.7 m), and 9.7 ft (3.0 m), respectively. The difference in surge levels is due to the method of calculation. In actuality, storm surges at Yorktown probably lie somewhere between these two predictions.

B. Physical Setting

1. Shore Morphology

The shore morphology is determined by long-term impact of the impinging wave climate after the waves have been altered by the nearshore bathymetry, tidal currents, and coastal structures. The orientation of the natural beaches in the study area can provide an indication of dominant coastal processes. A series of natural headlands and pocket beaches, referred to as the Yorktown Bays, occur approximately 2400 feet (730 m) downstream of Yorktown in the shoreline reach and upriver of Point of Rocks (Figure 7). In 1937, these pocket beaches did not exist per se but evolved over the next 50 years. As the headlands started to erode, cultural resources at Colonial National Historical Park were placed in jeopardy so the headlands were riprapped to ensure their stability.

Hardaway *et al.* (1991) document the long-term stability of these beaches based on review of historic aerial photography and 3 years of quarterly and post-storm profiles. The tangential sections (long linear reach) of these beaches are oriented toward 65° TN. This orientation is a direct indication that the dominant direction of the onshore wave approach is from the northeast (Hardaway *et al.*, 1991). Prior to the 1994 shoreline project at Yorktown, the tangential beach orientations on either side of the existing small breakwater exhibited similar orientations.

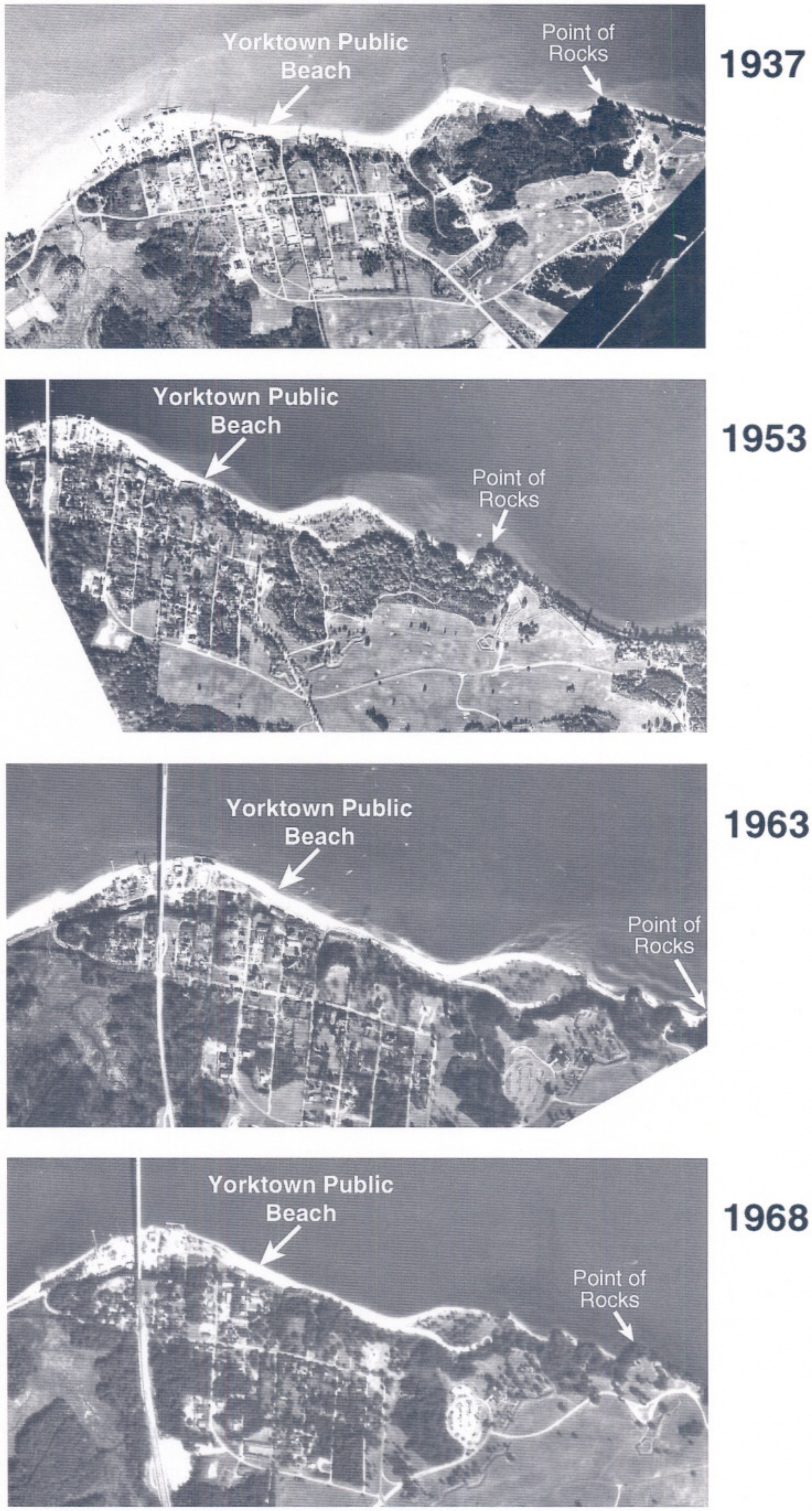


Figure 7. Historical aerial photos of study area in 1937, 1953, 1963, and 1968.

Historical erosion of the headlands and low banks just downriver of Yorktown provided sand to the adjacent beaches. As the shorelines have been progressively hardened with seawalls and revetments, they no longer supply beach material, and the beaches diminished along the Yorktown waterfront forcing action in the form of beach nourishment and building breakwaters.

Another important morphologic feature of the project shoreline is the noticeable shift in shoreline orientation that occurs just in front of the bathhouse area (Figure 4). This subtle change in the shoreline position provides an indication that northwesterly winds and current action in the river do exert some controls on the project shoreline.

2. Sediments

In general, the sediments at Yorktown beach consist of sand and gravel. The silt and clay content in the samples is less than five percent and will be disregarded in this analysis. Gravel was a significant portion of many samples, but this fraction was not analyzed into phi units. Additional sediment data are available in Appendix I.

Sediment samples were taken along 4 profile lines; these profiles are 3, 7, 10 and 13. Certain morphologic points were sampled consistently from date to date. The top of rock (TOR) (prior to fill) and backshore (BS) samples represent the area of the beach that is influenced by eolian transport and run-up from occasional storm events. Sediments were also taken at the base of rock (BOR) (prior to fill), BERM, last high tide (LHT), midbeach (MB), TOE, and offshore (OS). The toe of the beach is located at the break in slope between the beach face and the nearshore region. It is sometimes evidenced by a distinct change in sediment type. See Figure 5 for definition.

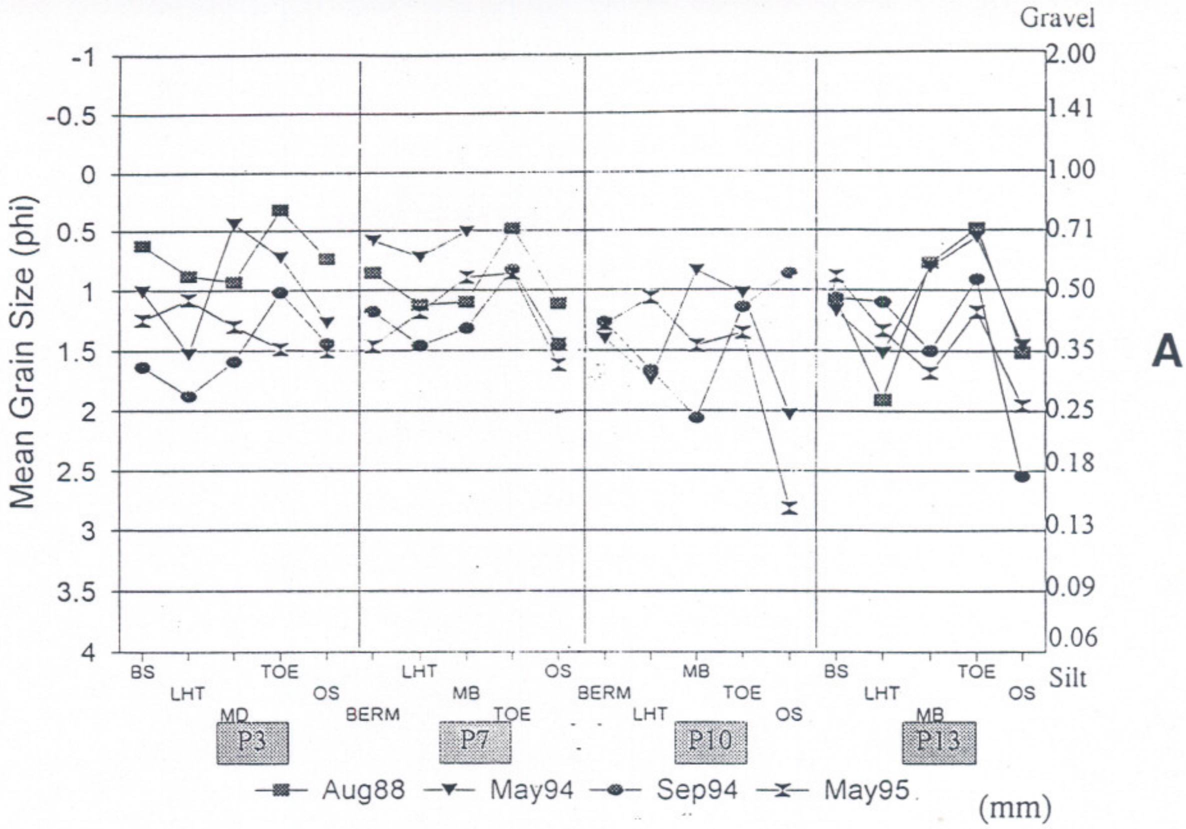
The grain size distribution of beach sand generally varies across shore and, to a lesser degree, alongshore as a function of the mode of deposition. The coarsest sand particles usually are found where the backwash meets the incoming swash in a zone of maximum turbulence at the base of the subaerial beach; here the sand is abruptly deposited creating a step or toe. Just offshore, the sand becomes finer. Another area of coarse particle accumulation is the berm crest, which is sometimes coincident with LHT, where runup deposits all grain sizes as the swash momentarily stops before the backwash starts. The dune or backshore generally contains the finest particles because deposition here is limited by the wind's ability to entrain and move sand (Bascom, 1959; Stauble *et al.*, 1993). This is typical of estuarine beaches in the Chesapeake Bay (Hardaway *et al.*, 1991).

The sorting of sediments can be described by the Inclusive Graphic Standard Deviation (Folk, 1980). The spread of the grain size distribution about the mean defines the concept of sorting. Well sorted sands will have a frequency distribution curve that is sharp peaked and narrow; this means only a few size classes are present (Friedman and Sanders, 1978). Poorly sorted sediments are represented by most size classes in the sample.

Figures 8A and 8B are plots of the mean grain size and sorting of the sand fraction of the sample. Profile 10 wasn't sampled in 1988 so it is not shown on the plots. In 1988, two years after the construction of the small breakwater and nourishment at Yorktown, the TOE was consistently the location of the coarsest material. Later dates show that either the TOE or MB were the coarsest.

Figures 9A through 9D show the range of locations where the sediment data was taken along each profile line sampled as well as the median sand size. The top brackets show the range in distance from where samples were taken in September 1994 and May 1995. The features shown on the bottom are the locations before the fill in May 1994. While the 1988 profile line is shown, the sediment sample locations are not shown on the plots. Since the beach became compartmentalized after the 1994 project, longshore trends probably don't exist. However, across shore trends may be seen in the data. The median sand size is for the sand fraction of the sample only. Generally, the data follow the model for sediment size distribution described above with the finest material in the backshore and offshore, but due to reduced beach width and subsequent fills at the beach as well as the high gravel content of the samples, many variations occur in the data as the beach fills undergo sedimentary distribution.

At profile 3, the entire range of samples have a smaller median size in May 1995 than in August 1988. This could be due to using fill material that had a smaller grain size than the native material. Cross-shore trends for both profiles 3 and 7 (Figures 9A and 9B) indicate that the midbeach and TOE samples are the coarsest samples, and the backshore and offshore samples are the finest. At profiles 10 and 13 (Figures 9C and 9D), samples were more variable. Profile 10 is located in the small embayment between the small breakwater and the primary breakwater so the variability could be expected since sand is easily shifted within the embayment depending on the wave conditions. The TOE at profile 13 had the largest grain size across the sample, but other morphologic features were variable.



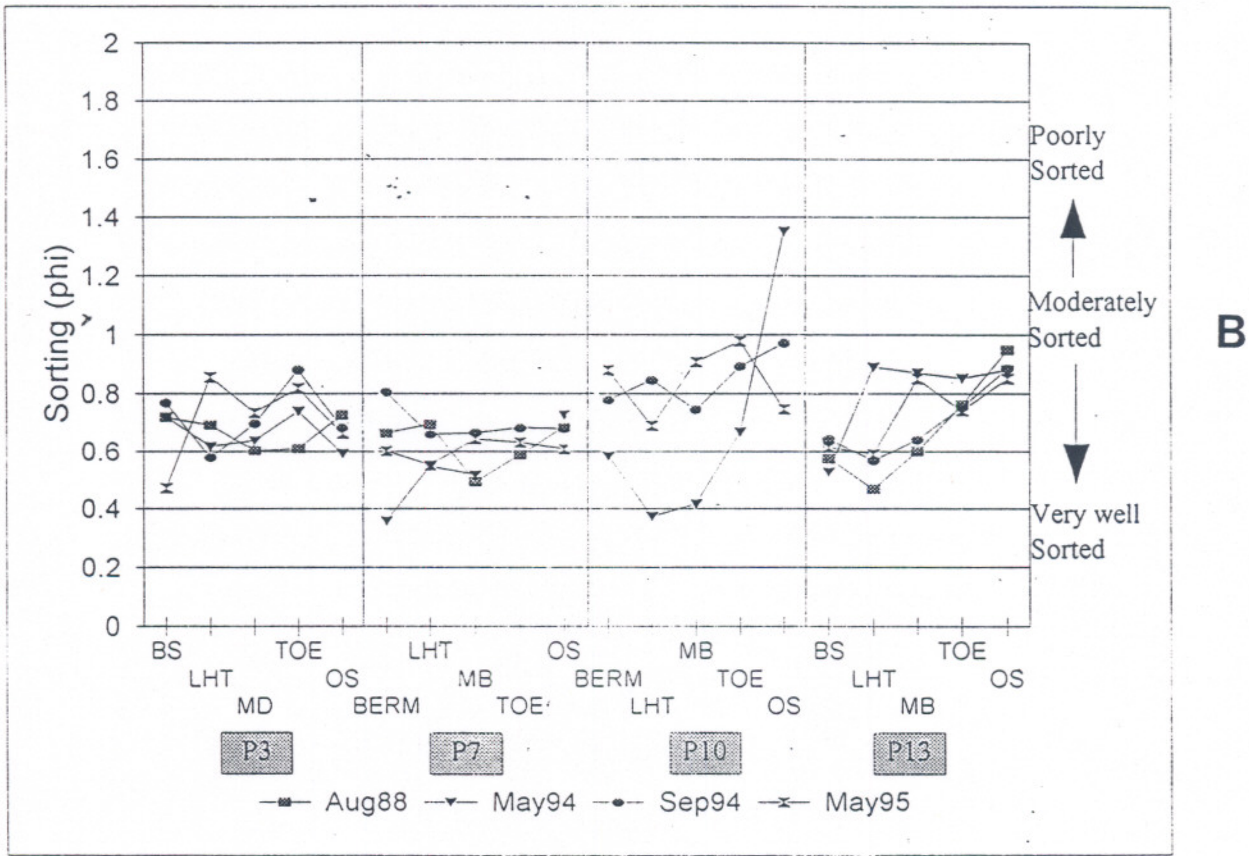
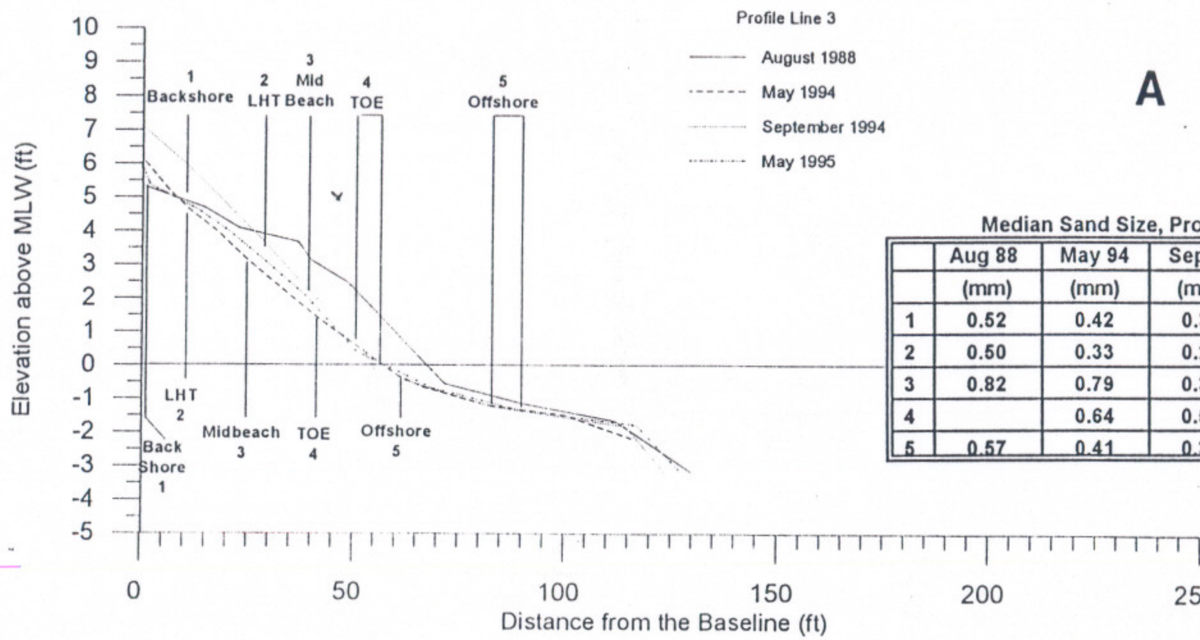
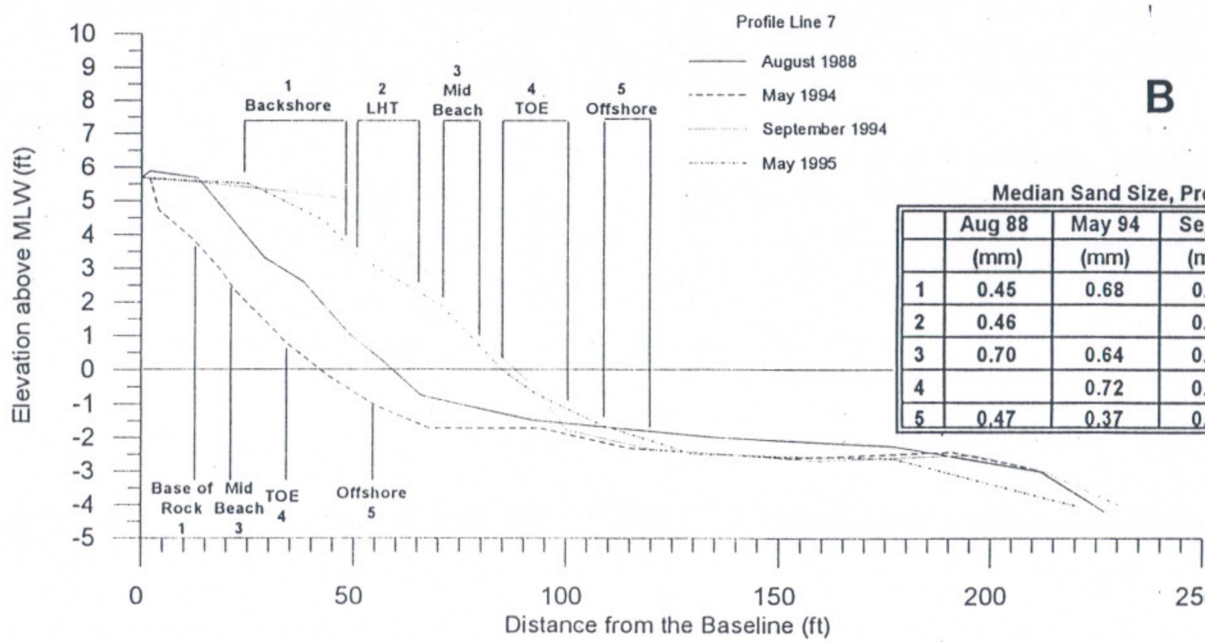


Figure 8. Results of sand analysis for A.) mean grain size and B.) sorting.



Median Sand Size, Profile 3

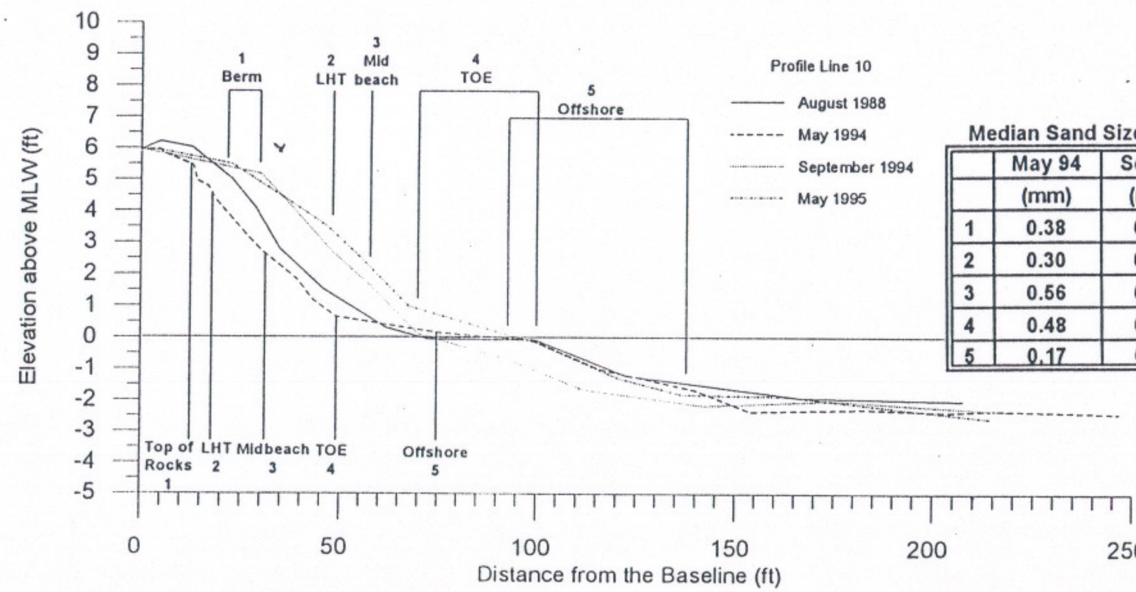
	Aug 88 (mm)	May 94 (mm)	Sep 94 (mm)	May 95 (mm)
1	0.52	0.42	0.32	0.42
2	0.50	0.33	0.27	0.47
3	0.82	0.79	0.32	0.40
4		0.64	0.52	0.35
5	0.57	0.41	0.37	0.37



Median Sand Size, Profile 7

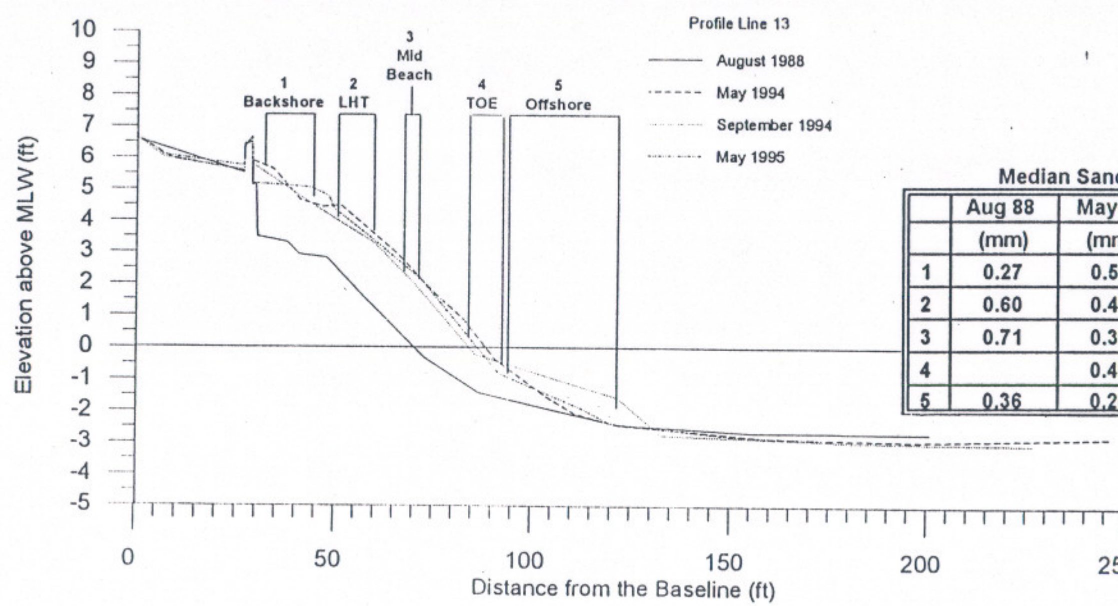
	Aug 88 (mm)	May 94 (mm)	Sep 94 (mm)	May 95 (mm)
1	0.45	0.68	0.43	0.36
2	0.46		0.34	0.43
3	0.70	0.64	0.41	0.53
4		0.72	0.54	0.54
5	0.47	0.37	0.36	0.34

Figure 9. Locations and range of locations for sediment samples as well as median sand size at A.) profile 3 and B.) profile 7.



Median Sand Size, Profile 10

	May 94 (mm)	Sep 94 (mm)	May 95 (mm)
1	0.38	0.45	0.42
2	0.30	0.31	0.55
3	0.56	0.23	0.38
4	0.48	0.49	0.46
5	0.17	0.62	0.12



Median Sand Size, Profile 13

	Aug 88 (mm)	May 94 (mm)	Sep 94 (mm)	May 95 (mm)
1	0.27	0.58	0.45	0.50
2	0.60	0.41	0.37	0.49
3	0.71	0.30	0.66	0.38
4		0.46	0.72	0.60
5	0.36	0.24	0.36	0.15

Figure 9. Locations and range of locations for sediment samples as well as median sand size at C.) profile 10 and D.) profile 13.

3. Sediment Transport

Wind/wave data for the study area indicate that strong northwesterly winds can have an impact along the Yorktown shore reach. For the most part, these events occur during subdued water levels where most of the sediment transport is along the beach face. The northeasterly and easterly winds that occur during elevated water levels are a greater factor in gross littoral transport. The northeast winds can create tremendous wave action in Chesapeake Bay proper, as well as over the local fetch. Yorktown is certainly influenced by wave attack generated within the Bay during strong northeasters. As previously stated, these waves enter the mouth of the York River and approach the shoreline with relatively low attenuation until reaching shallow nearshore depths. Breaking wave heights in excess of 3 ft (0.9 m) have been observed at the project site during strong northeasters.

Along much of the south side of the York River, the fastland is a bluff composed of stratified gravel, sand, silt and clay (US COE, 1989). Waves undercut the cliff causing face material to slump. Wave action removes the silts and clays leaving sand and gravel to form a beach. Subsequent wave action moves the sand alongshore or offshore. Generally sand moves from east to west along the York County shoreline; however, as described above, northwesterly storms tend to erode sediment from the cliffs upriver of Yorktown Public Beach. The sand then moves around the headland, under the Coleman Bridge and onto the public beach. Sand moved offshore is lost to the York River channel which comes in close to the public beach shoreline.

III. RCPWAVE

A detailed discussion of wave processes, sediment transport, and numerical modeling is beyond the scope of this report; the interested reader can refer to Appendix II for a listing of pertinent references. In order to evaluate the wave climate at Yorktown Public Beach, RCPWAVE was employed. The use of RCPWAVE to model the hydrodynamics at Yorktown assumes that only the offshore bathymetry affects wave transformation; the application does not include the effects of tidal currents. Due to program limitations, two grids (Figure 10) of the study region were digitized from a bathymetric map in order to characterize the east and northeast as well as the northwest conditions. Grid 1 was used for the east and northeast conditions while Grid 2 accommodates the northwest conditions affecting the Yorktown shoreline. The waves impinging the shoreline were predicted by the following process, developed and used during a previous projects (Hardaway *et al.*, 1991; Hardaway *et al.*, 1993; Milligan *et al.*, 1995):

1. Determine effective fetch for three directions. This was accomplished using procedures outlined in the U.S. Army Corps of Engineers Shore Protection Manual (1977) for Grid 1, east and northeast directions, and Grid 2, northwest, from the midpoint of the riverward extent of the grid.

2. Use the above data as input into SMB program which provides wave height, period, and length for a suite of wind speeds. In this case, wind speeds of 11 to 100 mph (5 to 45 m/sec) were used at approximately 9 mph (4 m/sec) increments. Specified surges ranged from 2 to 9 feet (0.6 to 2.7 m). The results of this step are used to create data files of wind speeds with associated wave heights and periods for the three subject directions.

3. Wind data for 5 years, 1985-1990, along with the data file from step 2, are the input to the program WINDOW (Suh, 1990). WINDOW takes the data file from step 2 and associates the wave heights and periods with wind speed and direction from each of the subject directions for each year to produce another data file of hindcast wave heights, periods, and directions through a series of vector-averaging steps. The limiting criterion is that the wind must be blowing from within the assigned directional window for at least nine hours. In other words, winds recorded at the Virginia Power's Yorktown Station must blow from, for example, 45° and 135° TN, for nine or more hours to qualify for the east directional window analysis. The northeasterly directional window analysis included winds from 0° to 90° TN. The northwesterly directional window analysis included winds from 300°-10° TN.

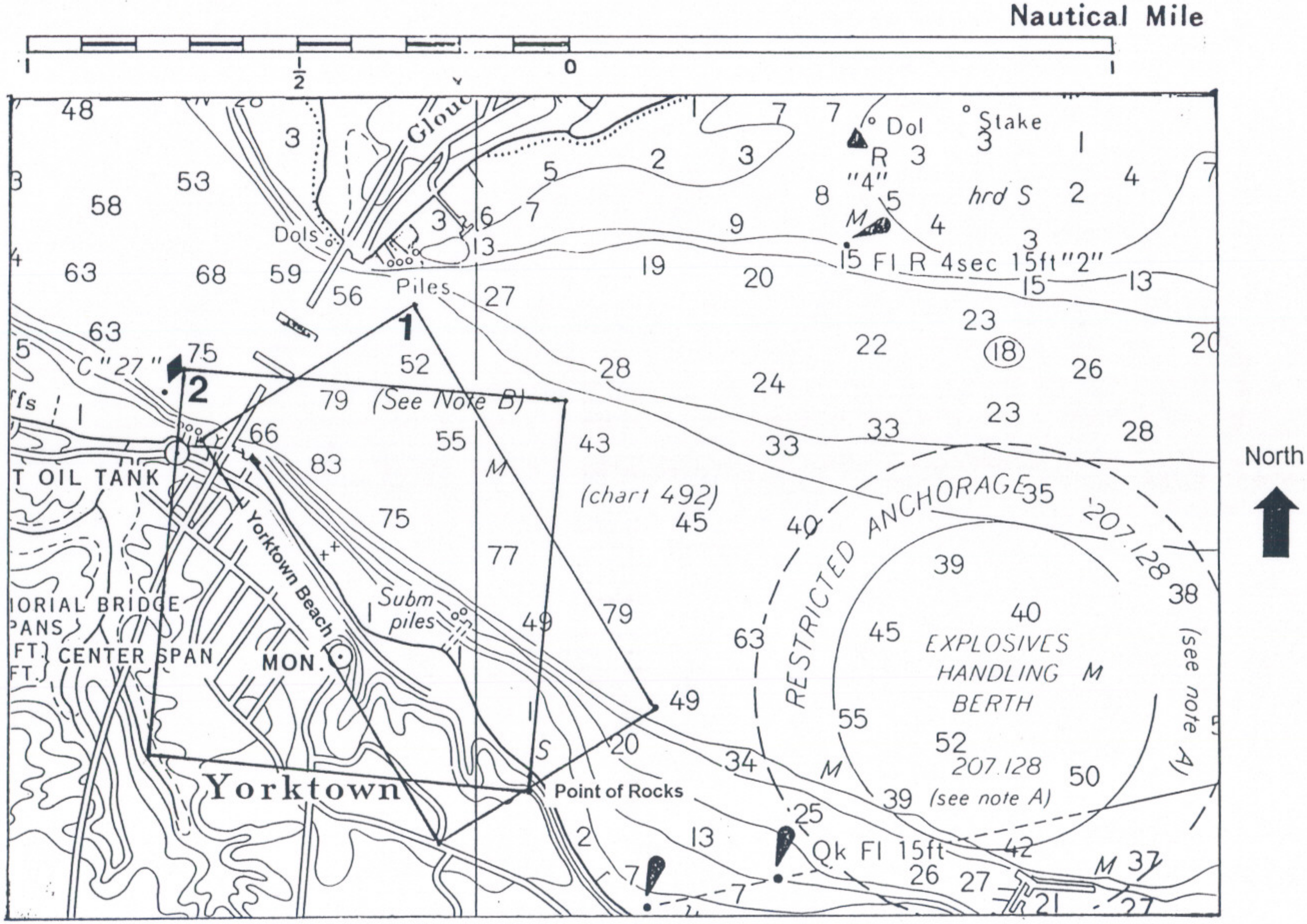


Figure 10. Bathymetric grid locations for running RCPWAVE model.

4. The result of step 3 are files for each year giving date, hour beginning, wave height, wave period, local wave direction, and duration of each qualifying event. These data are mean weighted to provide a weighted mean for wave height, period and direction with duration as the independent variable for each year.

5. The results of step 4 were mean-averaged for each year to produce two average, or modal, wave parameters for the directional window. These results were used as input into RCPWAVE. The modal conditions were run in RCPWAVE at MHW.

6. Three known storms were identified during the extent of the wind analysis: 4 November 1985, 13 April 1988, and 8-9 March 1989. The wind speeds and directions for each storm event were pulled from the data and the maximum conditions were noted. The maximum wind speed was compared manually to the data file created in step 2 rather than using the WINDOW program described in step 3. The wave parameters obtained for each event were used as storm input to RCPWAVE. Since the storms were northeasters, they were run on Grid 1.

7. Tide data for the same storm periods were obtained from VIMS's archive, and the maximum height the tide reached during the storm was used as the surge for RCPWAVE input. The four modal conditions and three storm conditions input into RCPWAVE are listed in Table 1.

Table 1. Modal and storm input conditions for RCPWAVE.

Run	Figure Number	Height (m)	Period (secs)	Direction (°TN)	Surge (m)	Duration (hrs)
Grid 1, Modal, NE 1	11A	0.75	3.14	212	0.7	19
Grid 1, Modal, NE 2	11B	0.48	2.60	234	0.7	17
Grid 1, Modal, E 1	11C	0.47	2.59	255	0.7	17
Grid 1, Modal, E 2	11D	0.45	2.55	284	0.7	17
Grid 2, Modal, NW 1	12A	0.77	3.15	146	0.7	15
Grid 2, Modal, NW 2	12B	0.64	2.92	167	0.7	16
Storm - Nov 1985	13A	1.39	4.23	261	1.9	NA
Storm - Apr 1988	13B	1.50	4.34	244	1.9	NA
Storm - Mar 1989	13C	1.39	4.23	241	1.7	NA

RCPWAVE takes an incident wave condition at the seaward boundary of the grid and allows it to propagate shoreward across the nearshore bathymetry. Frictional dissipation due to bottom roughness is accounted for in this analysis and is relative in part to the mean sand size. Waves also tend to become smaller over shallower bathymetry and remain larger over deeper bathymetry. In general, waves break when the ratio of wave height to water depth equals 0.78 (Komar, 1976).

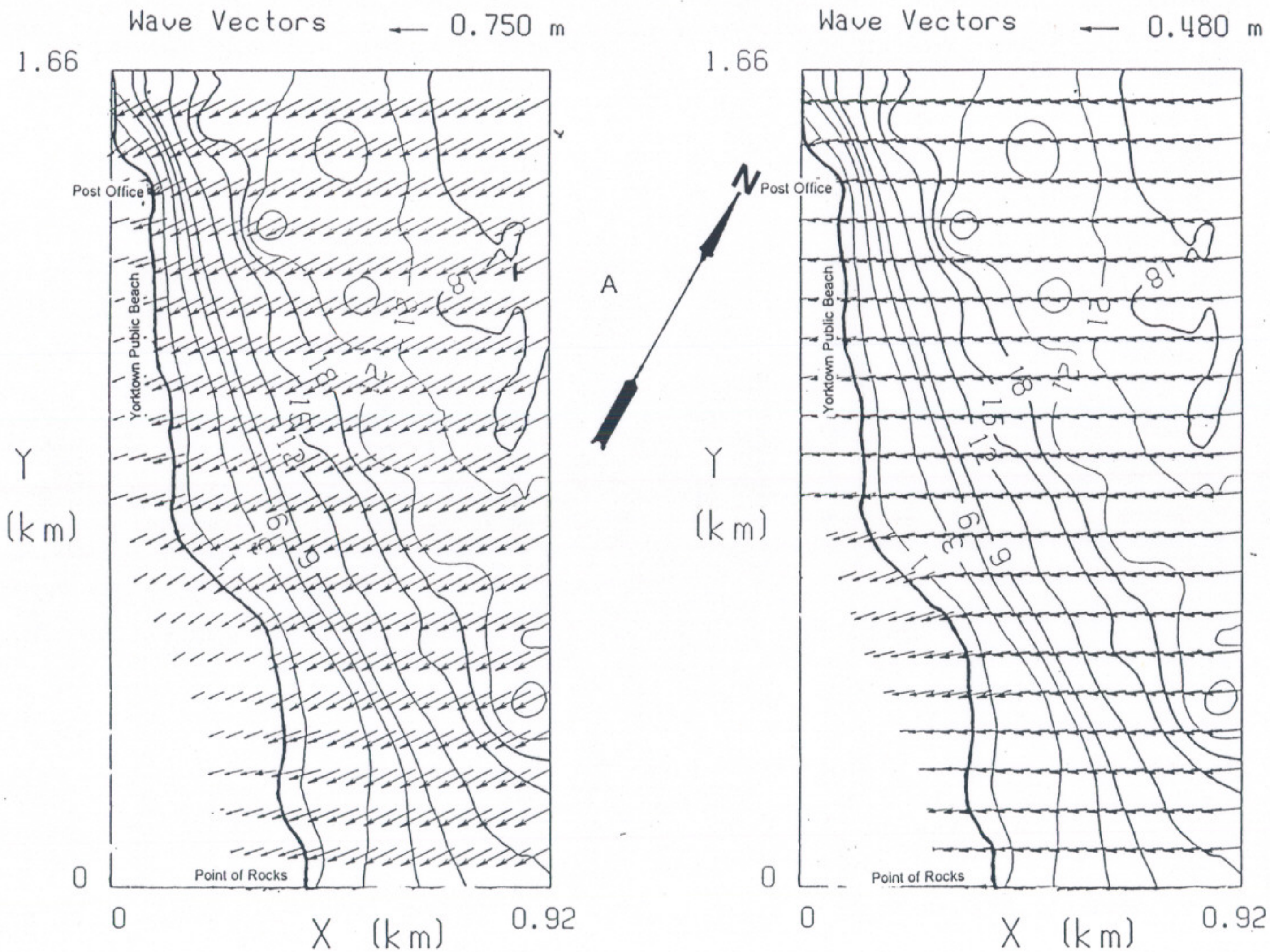
Upon entering shallow water, waves are subject to refraction, in which the direction of wave travel changes with decreasing depth of water in such a way that wave crests tend to become parallel to the depth contours. Irregular bottom topography can cause waves to be refracted in a complex way and produce variations in the wave height and energy along the coast (Komar, 1976).

The results of the modeling efforts, indicate that the project shoreline is subject to slightly oblique breaking wave during northeasterly storm events. This finding is consistent with the geomorphic expression of the pocket beaches in the vicinity, which tend to exhibit offsets oriented toward the north-northeast.

Figure 11A through 11D shows the 4 modal conditions run on Grid 1 hindcast for this shoreline reach. Figures 11A and 11B show wind-generated wave conditions from approximately the northeast. Figures 11C and 11D show approximately the waves coming from the east. All four conditions have very little attenuation of waves by the bathymetry. Incoming waves are generally not influenced by the nearshore region with very little reduction in wave height or wave refraction. Waves coming up the river (Figure 11D) do experience some attenuation and refraction just upriver of the large headland northwest of Point of Rocks. However, most incident waves approach the shoreline at a slight angle.

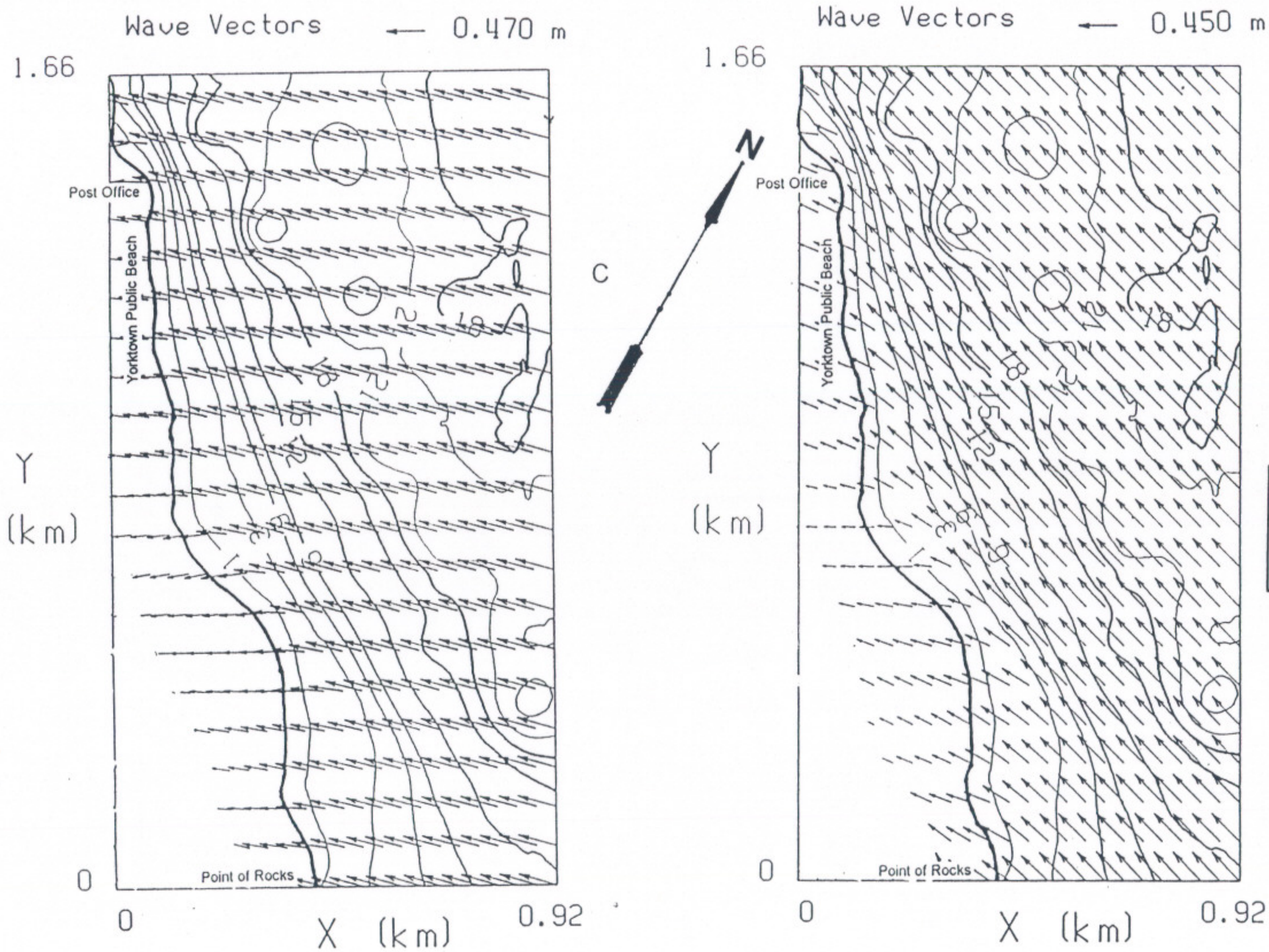
Figure 12A and 12B shows the northwest modal conditions run on Grid 2. In general, these waves undergo much more attenuation and refraction than the northeast and east modal conditions. Upriver of the U.S. Post Office, however, the waves approach the shoreline at an angle tending to drive sediment downriver towards the Public Beach. Along the Public Beach and the CNHP waves generally break parallel to the shoreline.

Figure 13A through 13C are plots of the storm conditions run on Grid 1. Figure 13A are the maximum conditions during the November 1985 storm; Figure 13B are maximum conditions for the April 1988 storm; and Figure 13C are maximum conditions for the March 1989 storm. In general, for all three storms there was very little wave attenuation. However, close to the shoreline, there was some



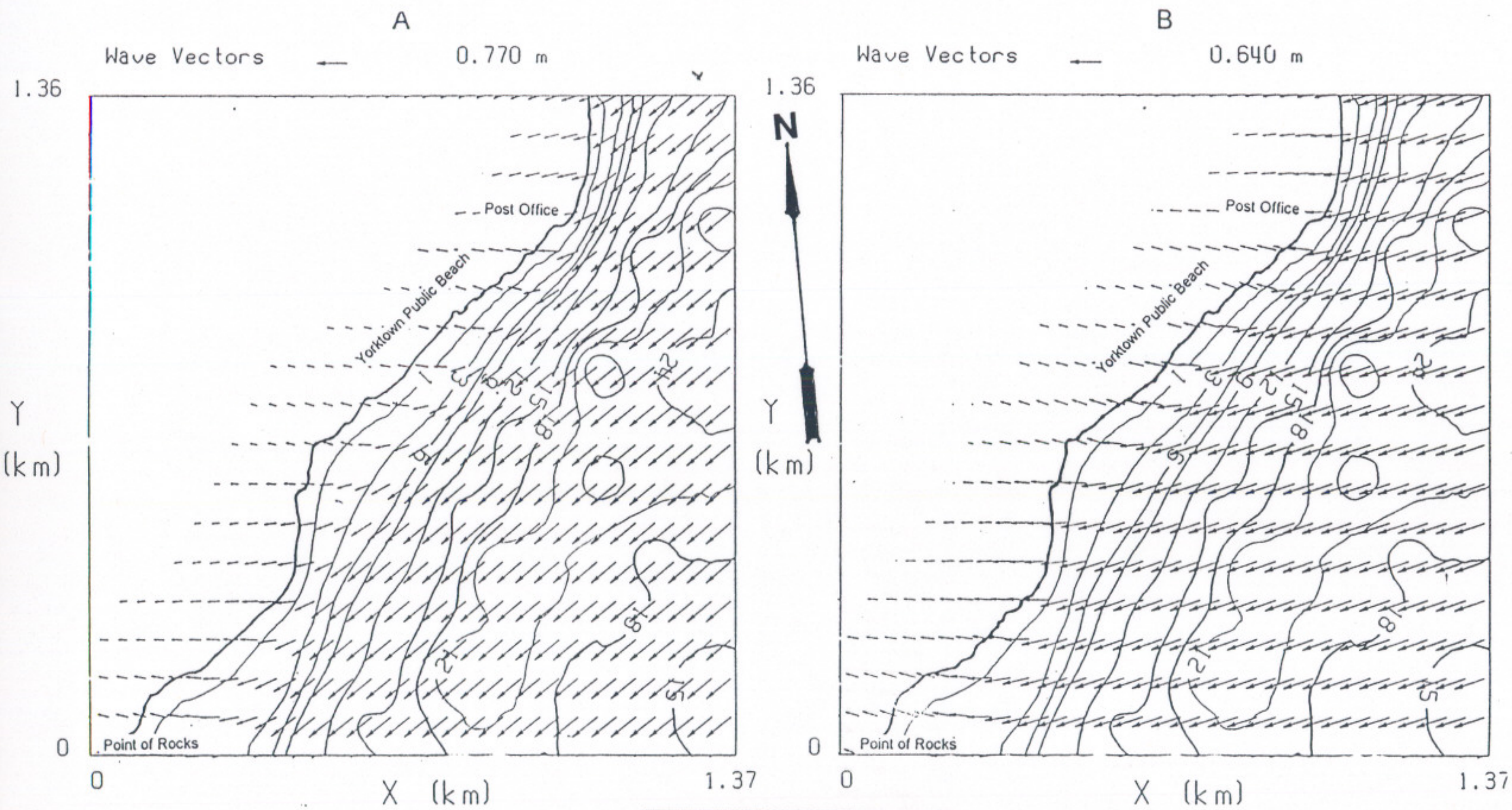
	A	B
H(m)	0.75	0.48
T(sec)	3.14	2.60
Dir(°TN)	212	234

Figure 11. Wave vector plots for modal conditions created from northeasterly winds and run on Grid 1 at MHW.



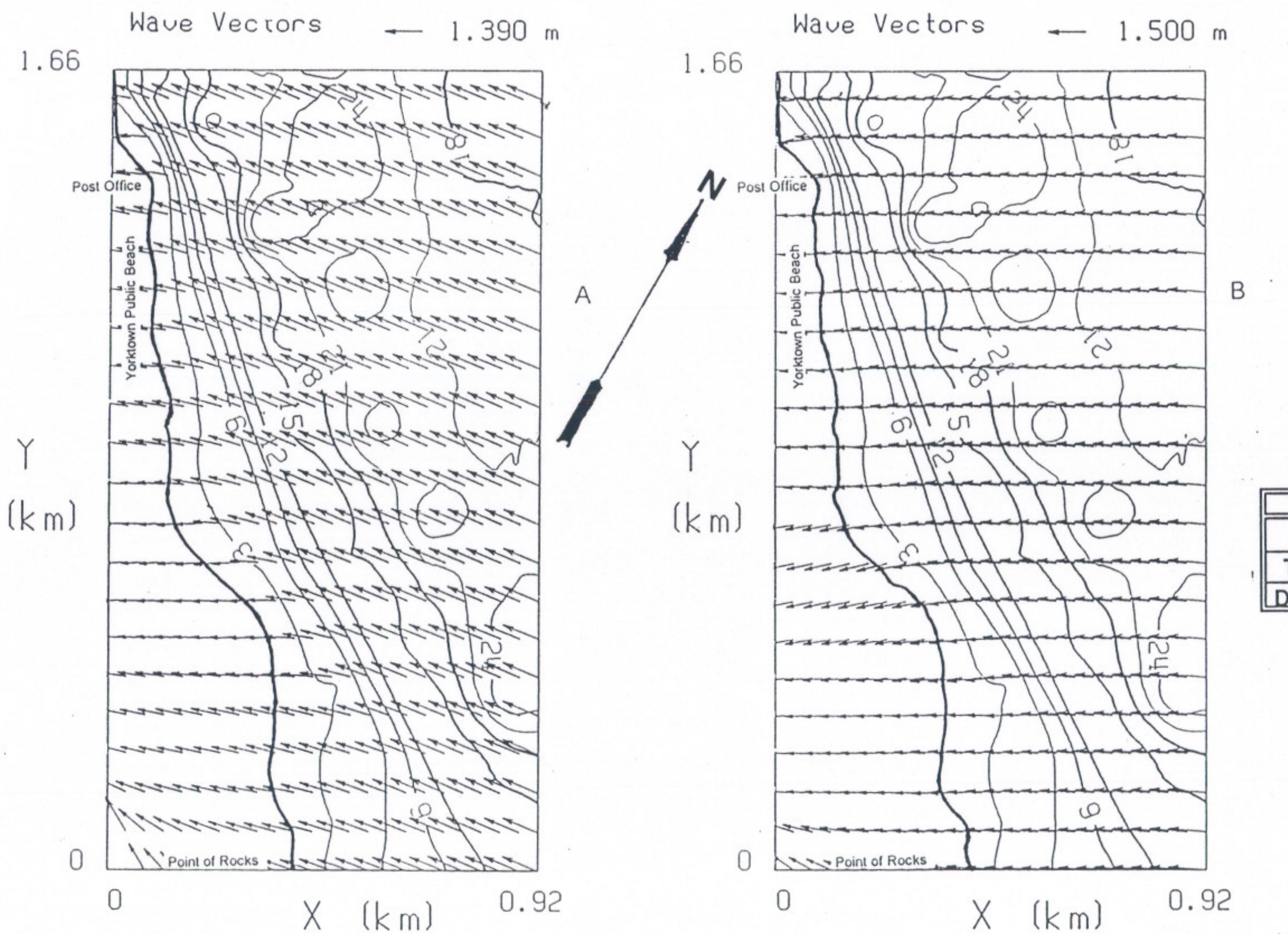
	C	D
H(m)	0.47	0.45
T(sec)	2.59	2.55
Dir(°TN)	255	284

Figure 11. Wave vector plots for modal conditions created from easterly winds and run on Grid 1 at MHW.



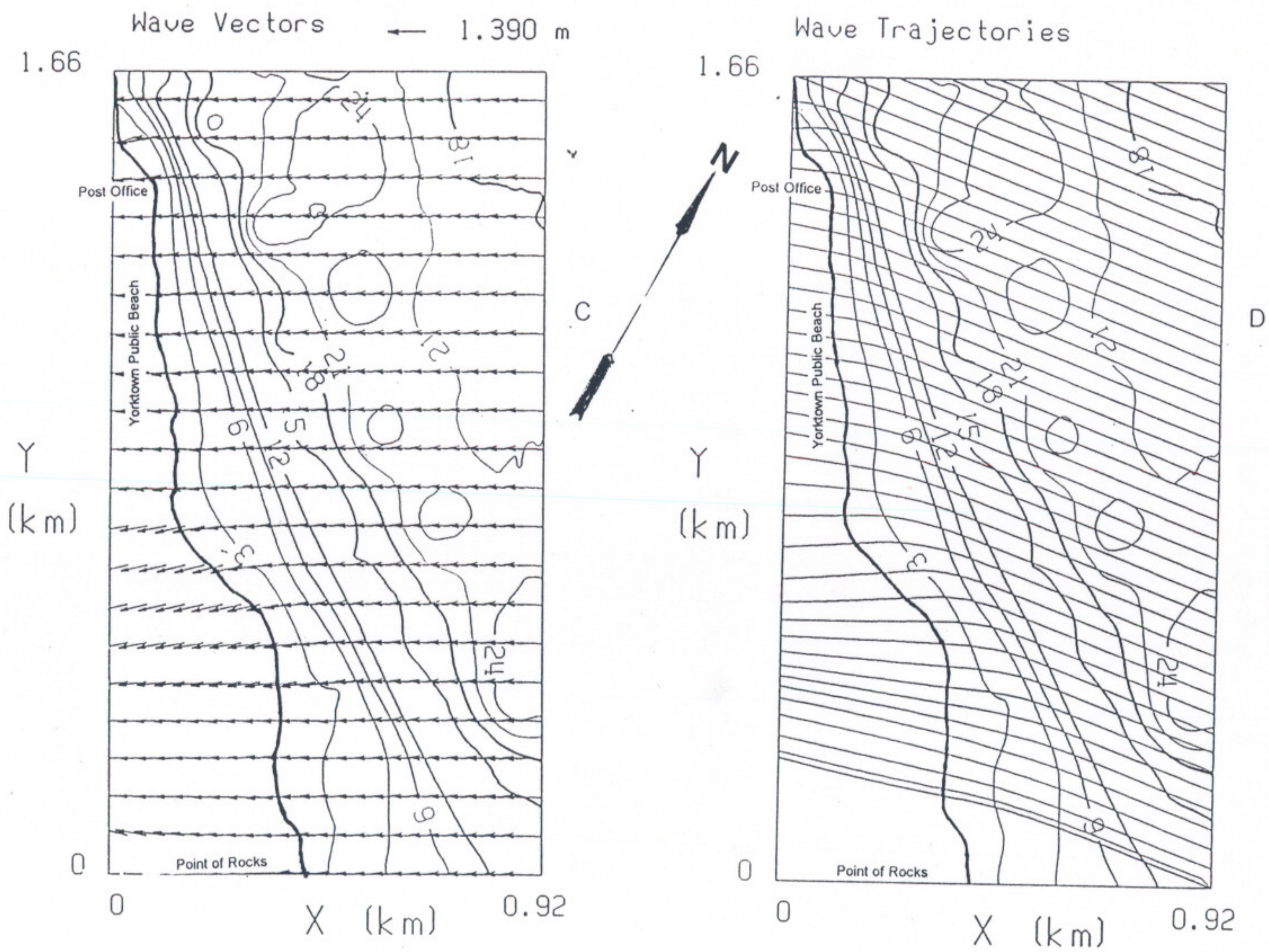
	A	B
H(m)	0.77	0.64
T(sec)	3.15	2.92
Dir(°TN)	146	167

Figure 12. Wave vector plots for modal conditions created from northwesterly winds and run on Grid 2 at MHW.



	A	B
H(m)	1.39	1.50
T(sec)	4.23	4.34
Dir(°TN)	261	244

Figure 13. Wave vector plots for maximum November 1985 storm conditions in A.) November 1985 and B.) April 1988.



	C	D
H(m)	1.39	1.39
T(sec)	4.23	4.23
Dir(°TN)	241	261

Figure 13. C.) Wave vector plots for maximum March 1989 storm conditions.
D.) Wave trajectory plot under storm conditions.

wave refraction particularly near the headland upriver of Point of Rocks. Figure 13D is a wave trajectory plot indicating the distribution of energy across a shoreline. Generally, there was no concentration of wave energy along a particular stretch of shoreline under conditions like those of the November 1985 storm.

IV. BEACH CHARACTERISTICS

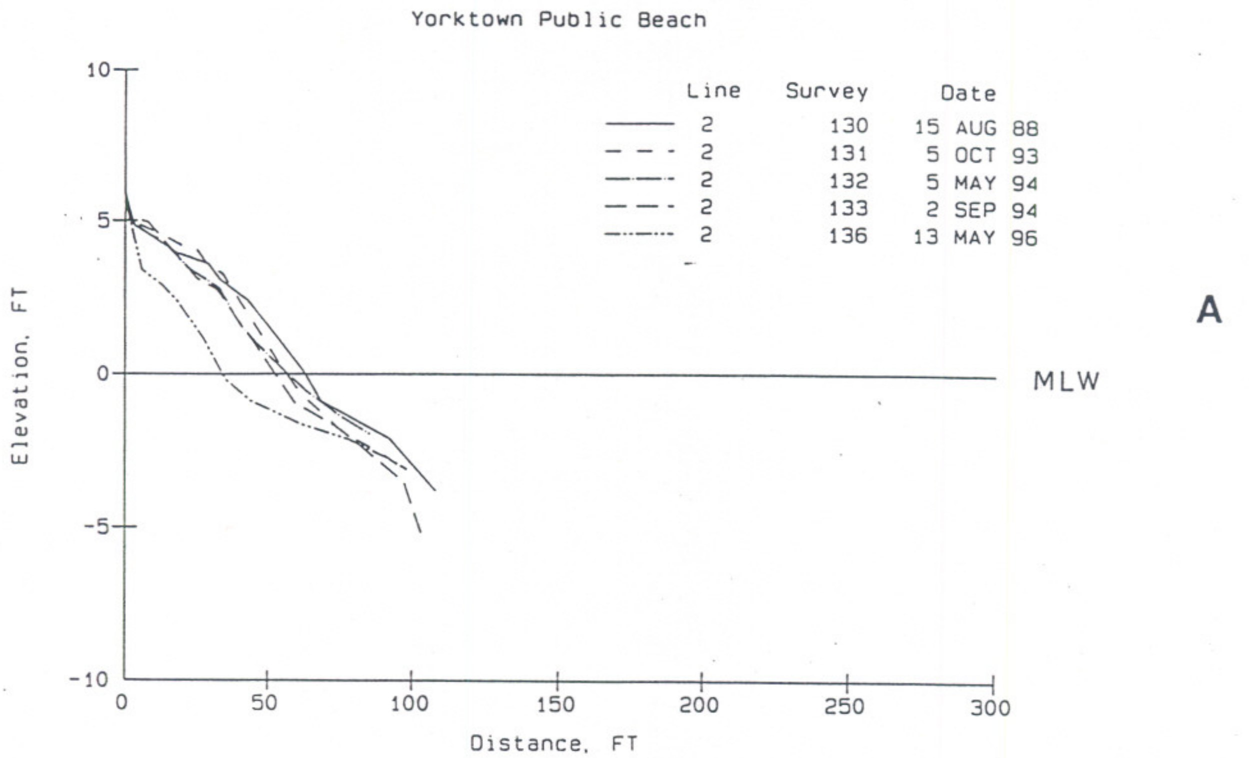
A. Beach Profiles and their Variability

Sixteen profile lines (Figure 4) were established at Yorktown Public Beach to document changes along the shoreline. Only fourteen profile lines were part of the original baseline; two profiles, 6.5 and 8.5, were added after the 1994 breakwater and beach fill project in order to better monitor changes. Profiles 1 through 4 are located in front of the parking lot and bathhouse. The baseline shifts back between profiles 4 and 5. Profiles 5 through 10 are located on the sidewalk next to Water Street. Profiles 12 through 14 include the seawall.

Figure 14, A through H, are plots of profile data showing the beach at five significant dates. 15 August 1988 is approximately two years after the earlier nourishment project. 5 October 1993 and 4 May 1994 are prior to the 1994 breakwater and fill project. 2 September 1994 was taken just after the project was completed, and 13 May 1996 shows the shoreline at the latest profile date. Additional profile data are shown in Appendix III.

Profile 2 (Figure 14A) is representative of profiles 1 to 4. Since 1988, this unprotected section of the beach has receded, particularly in the last two years. The breakwaters are capturing sand traveling upriver that previously passed through the beach to these profiles. The significant amount of erosion at profiles 5 through 9 (Figure 14B, 14C, 14D, 14E) between August 1988 and May 1994 was the impetus for the breakwater and fill project. After the project, profiles 5 and 7, on either side of the westernmost breakwater, have eroded somewhat as the shoreline adjusted to the predicted pocket beach planform. Profiles 6 and 9 (Figure 14C and 14E) show the position of the two breakwaters constructed in 1994. Since the project, the regions behind the breakwaters have accreted creating a subaerially attached tombolo.

Profiles 10 and 11 (Figure 14F and 14G) had only slight erosion between 1988 and May 1994. This is due to the small breakwater installed at profile 11 in 1986. Since the fill project, the subaerial beach at profile 10 has accreted a substantial amount. The subaerial tombolo at profile 11 has accreted somewhat since the 1994 project. Profile 14 (Figure 14H), which is located on the seawall and is representative of profiles 12 and 13, has been accreting since 1988. The small breakwater is accumulating sand that the littoral transport system is moving upriver.



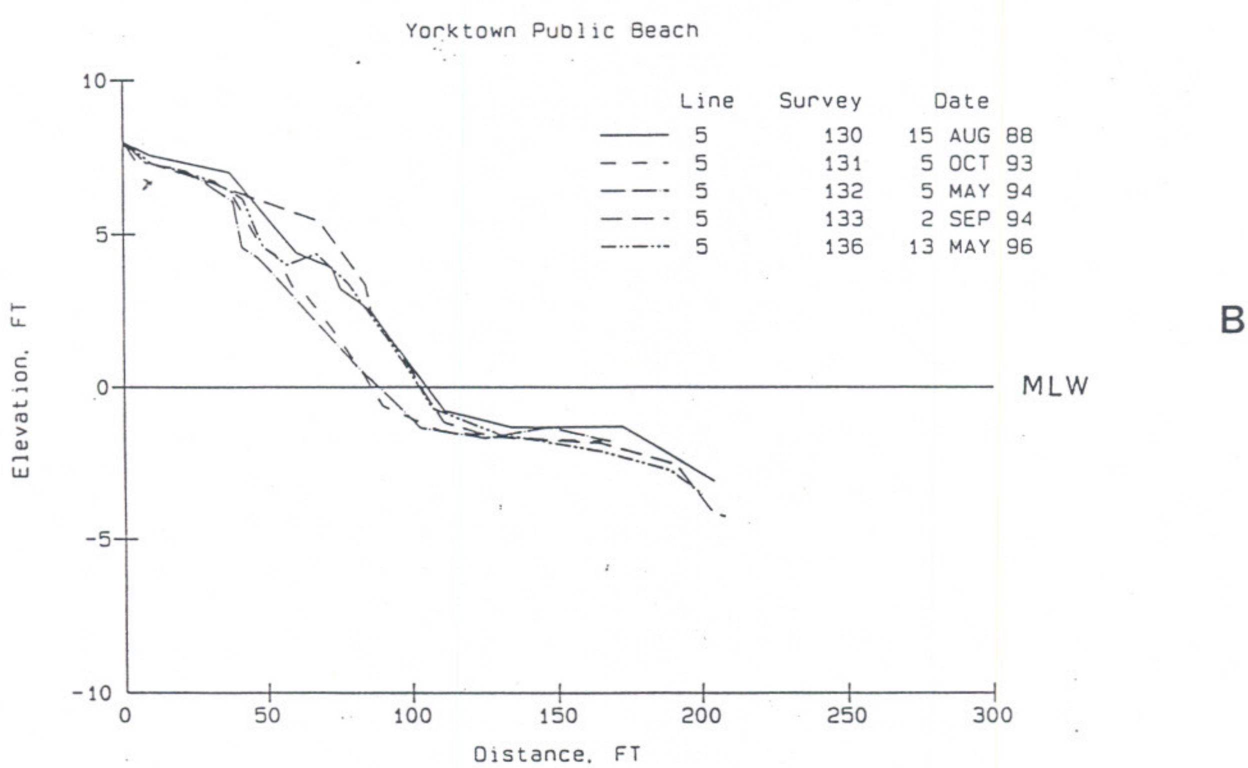
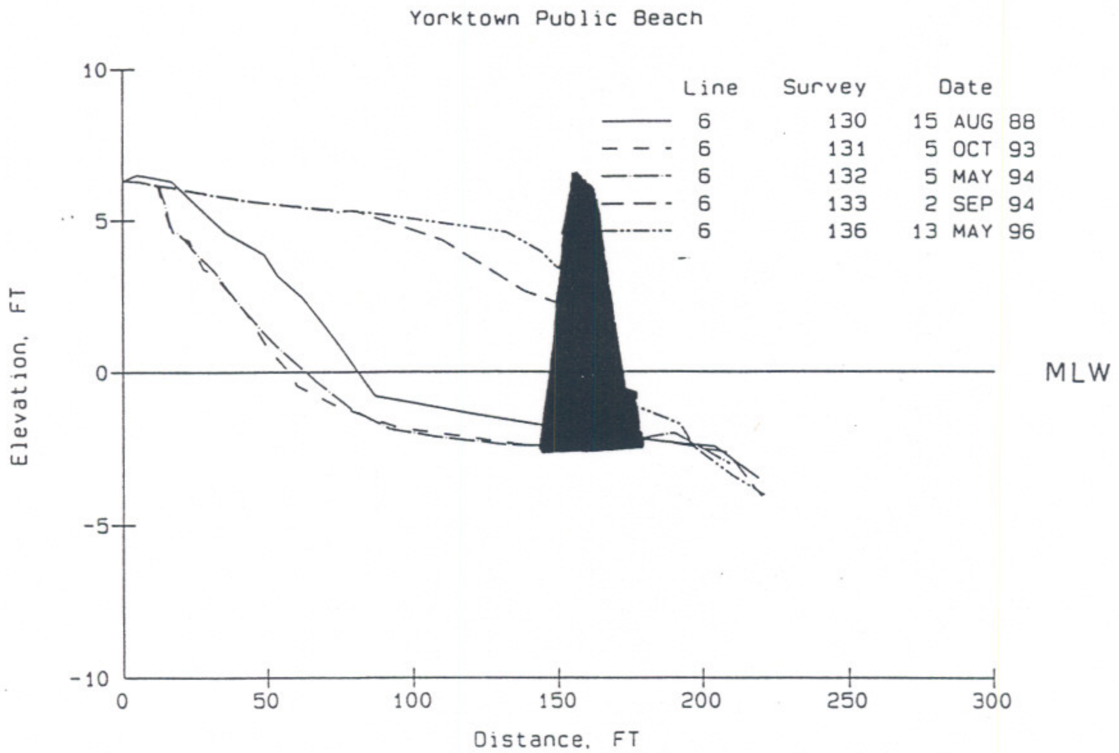
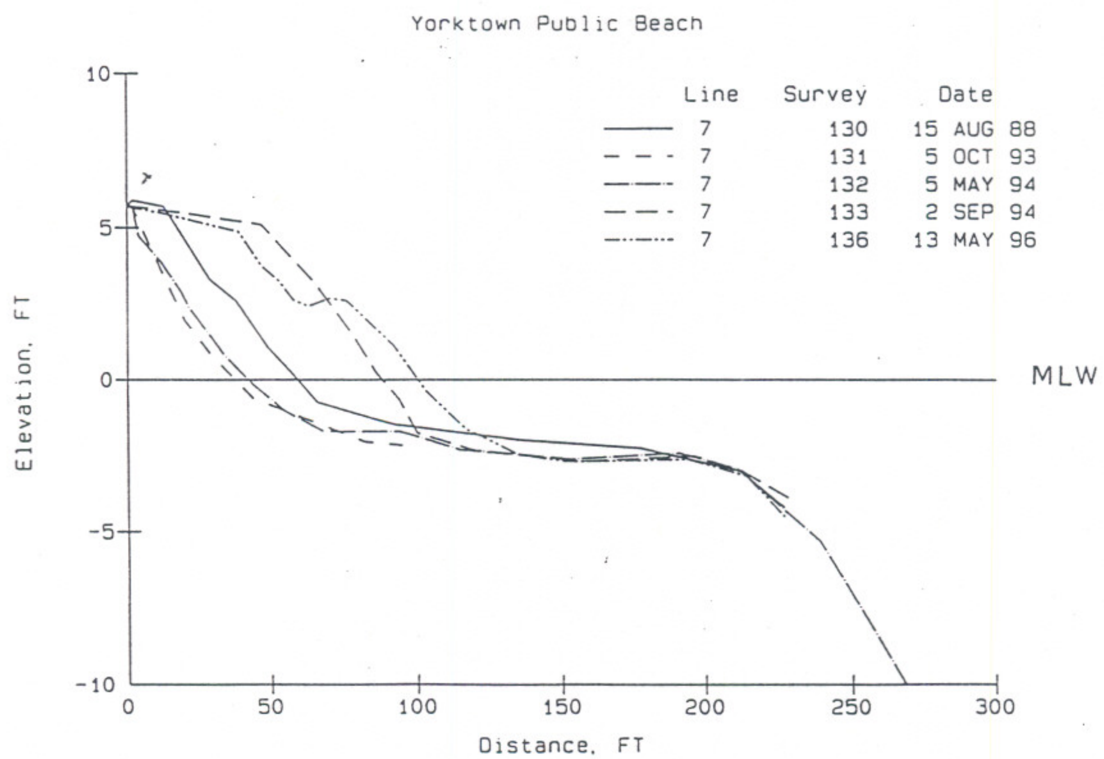


Figure 14. Plot depicting change at A.) profile 2 and B.) profile 5.

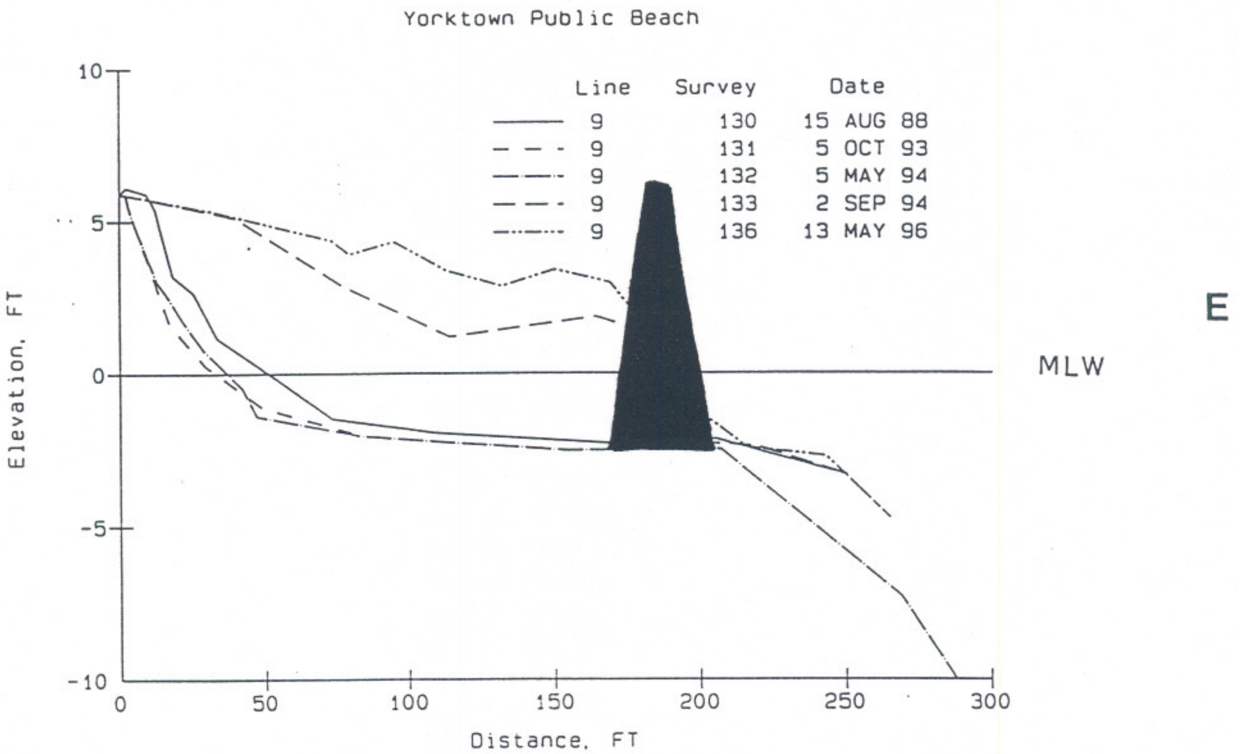


C



D

Figure 14. Plot depicting change at C.) profile 6 and D.) profile 7.



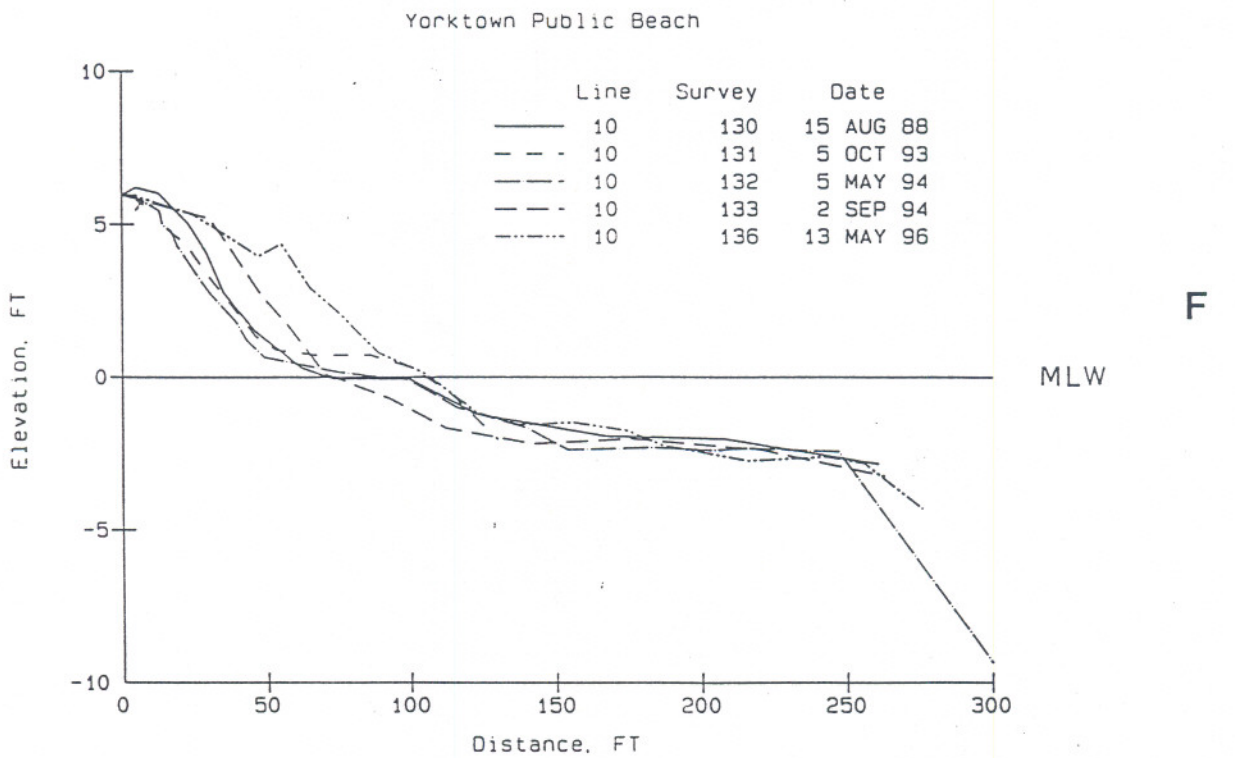
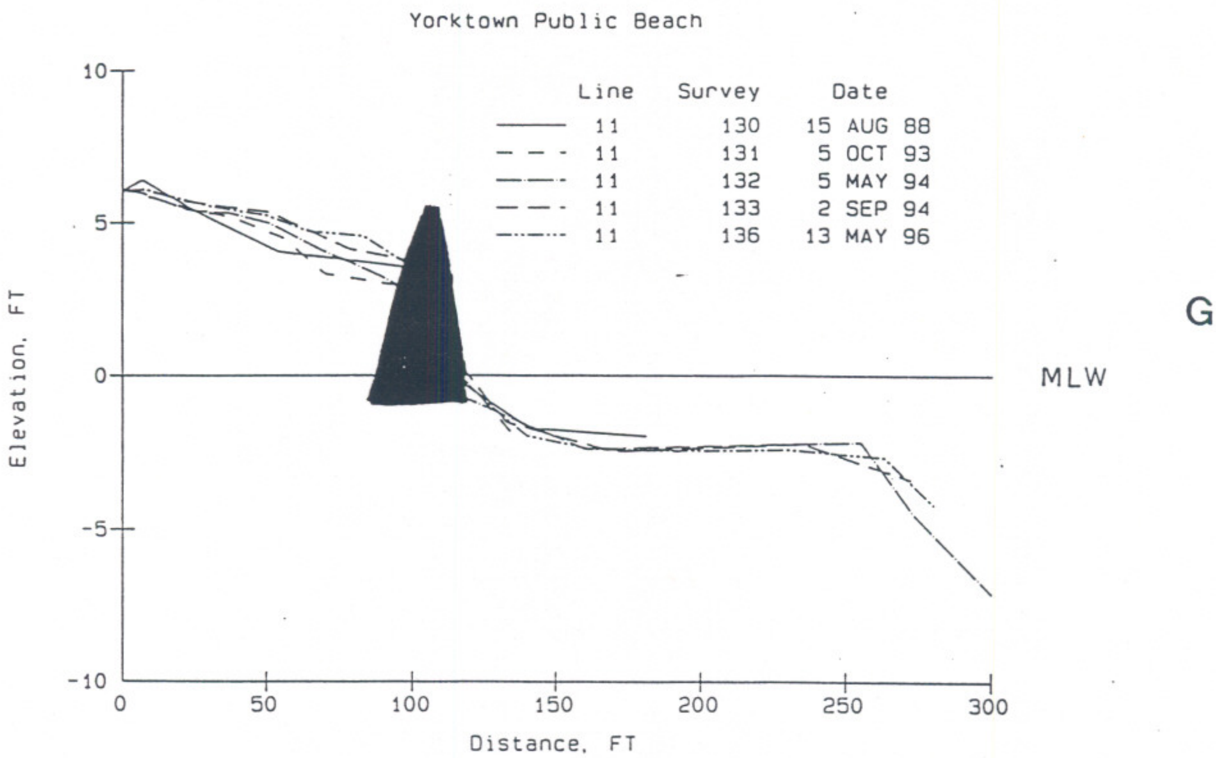


Figure 14. Plot depicting change at E.) profile 9 and F.) profile 10.



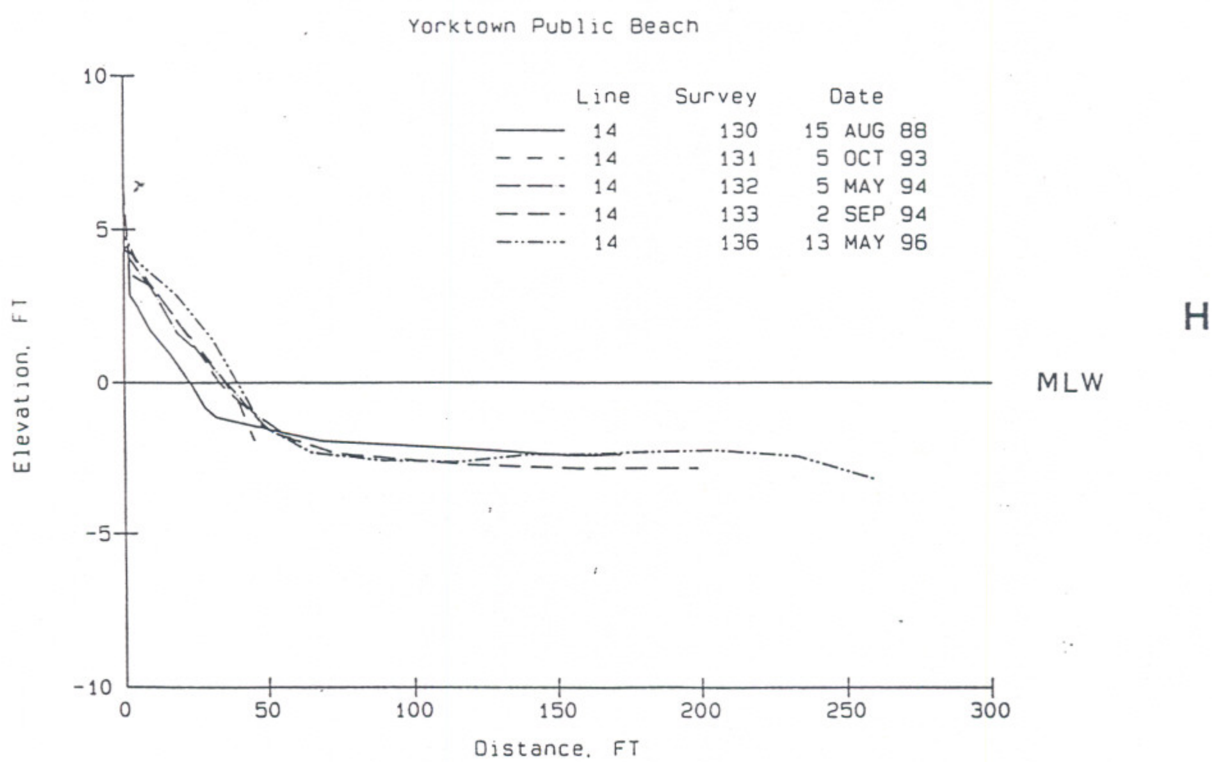


Figure 14. Plot depicting change at G.) profile 11 and H.) profile 14.

B. Variability in Shoreline Position

The position of MHW can be used to demonstrate changes in the beach shape over time. Figure 15 shows the distance to MHW from the baseline for each profile line. The approximate position of the breakwaters are shown. The beach fill in 1989 was not monitored. The net average rate of change measures the change in distance to MHW between two dates. In general, profiles 1 through 4 have been eroding since 1986. Between June 1986 and May 1994, profiles 1 through 4 had a net average erosion rate of 1.9 ft/yr (0.6 m/yr). However, since the project was installed in 1994, these same profiles have lost distance to MHW at a net average rate of 8.1 ft/yr (2.5 m/yr). Profiles 1 and 2 seem to be eroding more than profiles 3 and 4.

Profiles 5 through 10 lost an average of 34 feet (10.4 m) between June 1986 and May 1994, creating a net average erosion rate of 4.2 ft/yr (1.3 m/yr). Placement of renourishment material along these profiles was variable; profile 5 showed an additional 22 feet (6.7 m) distance to MHW while profile 6 gained 106 feet (32 m). Overall, profiles 5 through 10 gained an average of 52 feet (16 m) distance to MHW between May and September 1994. This same section of the beach has had a varied response to the fill material. Between September 1994 and May 1996, profiles 5 and 8 lost 1 and 13 feet, respectively (0.3 and 4 m) distance to MHW while profile 9 gained 86 feet (26.2 m). The beach is adjusting into the predicted planform for pocket beaches.

Profile 11 has had very little net change between 1986, after the small breakwater was installed, and 1996. The distance to MHW has only changed by -2 feet (0.6 m). Profiles 12 through 14, on the other hand, are accreting. Between 1986 and 1996, these profiles have gained an average of 19 feet (5.8 m) distance to MHW, creating a net average accretion rate of 1.9 ft/yr (0.6 m/yr).

C. Beach and Nearshore Volume Changes

The amount of material either lost or gained along the shore zone can be measured by changes in area and converted to volumes along a profile line or in a shore cell. Subaerial beach volume calculations extend from the baseline to MLW whereas nearshore calculations extend riverward from MLW. Shore cells are defined by two profile lines so the calculations for each cell are an average of the properties of the profile lines defining the cell. Cell 1 is between profiles 1 and 2, cell 2 occurs between profiles 2 and 3, and so on. Profiles 6.5 and 8.5 are disregarded in this analysis since they have only been profiled since September 1994.

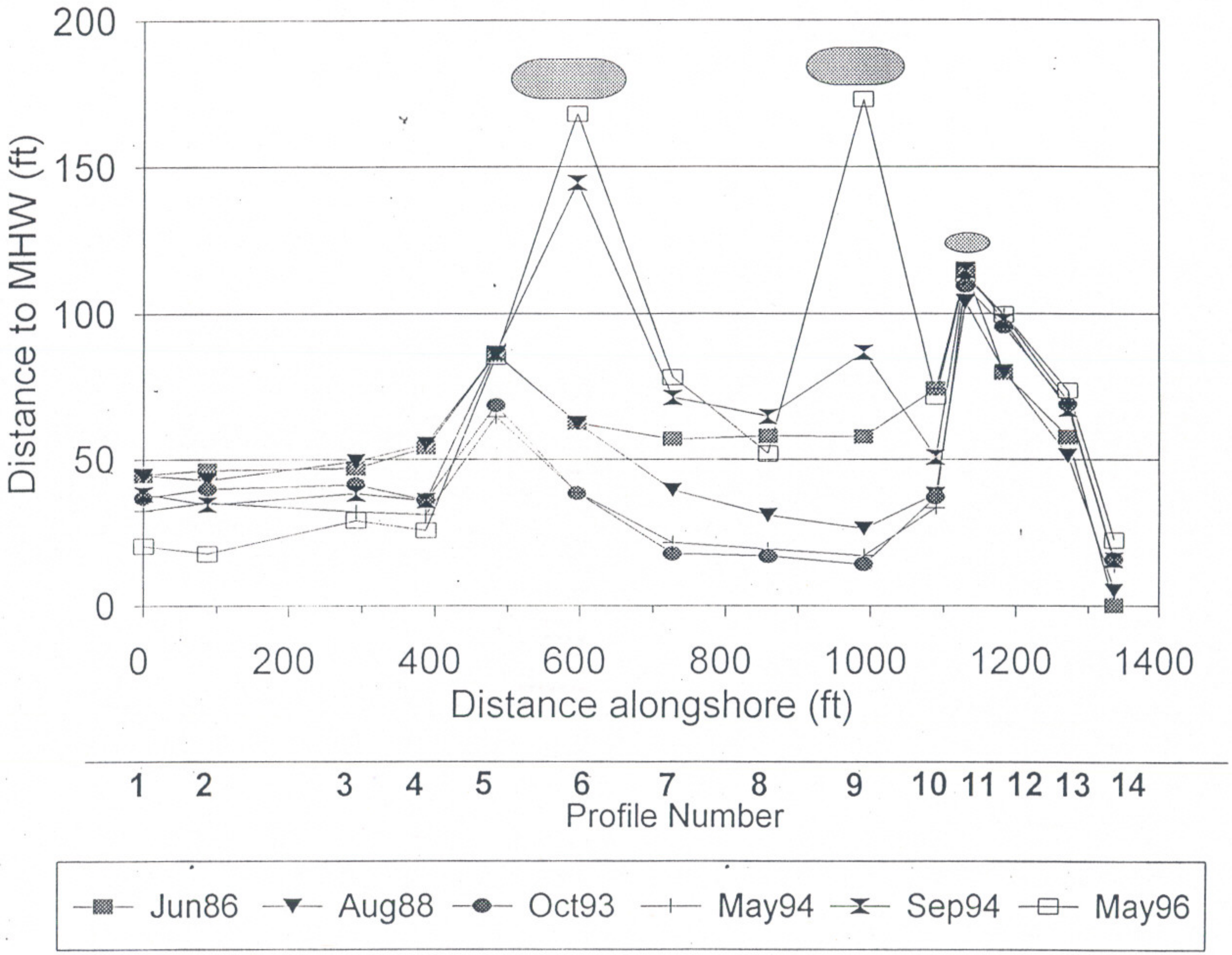


Figure 15. Distance to MHW from the baseline.

Figure 16 shows the response of the subaerial beach in cy/ft for the small breakwater and fill project in 1986 (Figure 16A) and the 1994 Shoreline Erosion Control Project (Figure 16B). Between June 1986 and February 1987, the shoreline fronting the sidewalk along Water Street was the hardest hit. In particular, cells 8 and 9, profiles 8 through 10, lost about 5.5 cy/ft (14 m^3/m). Cells 1 and 2 also had substantial erosion during this time period, but cell 13 actually accreted. Between February 1987 and August 1988, the shore in front of the sidewalk was again the hardest hit by erosion. Cells 1 through 3 actually accreted as did cell 12, which is just updrift of the small breakwater.

Figure 16B demonstrates volume changes after the 1994 project. Immediately following the project, between September 1994 and May 1995, most of the shore cells accreted along the section of beach in front of the sidewalk next to Water Street. Cell 7, which is defined by profiles 7 and 8, showed a net loss as the shoreline adjusted to the breakwater and fill project. Cells 1 through 4 showed a net loss in volume between both September 1994-May 1995 and May 1995-December 1995. Between December 1995-May 1996, cells 2 through 11 showed a net gain in volume. The prior analyses only described net changes between September 1994 and May 1996, but a detailed analysis of cells 2 through 4 actually showed a gain in volume between December 1995 and May 1996 at the same cells previously described as erosional. This gain in volume is probably due to a seasonal component of the littoral transport system. Northwesterlies move sand under the Coleman Bridge to profiles 1 through 5 where the sand accumulates updrift of the winged breakwater.

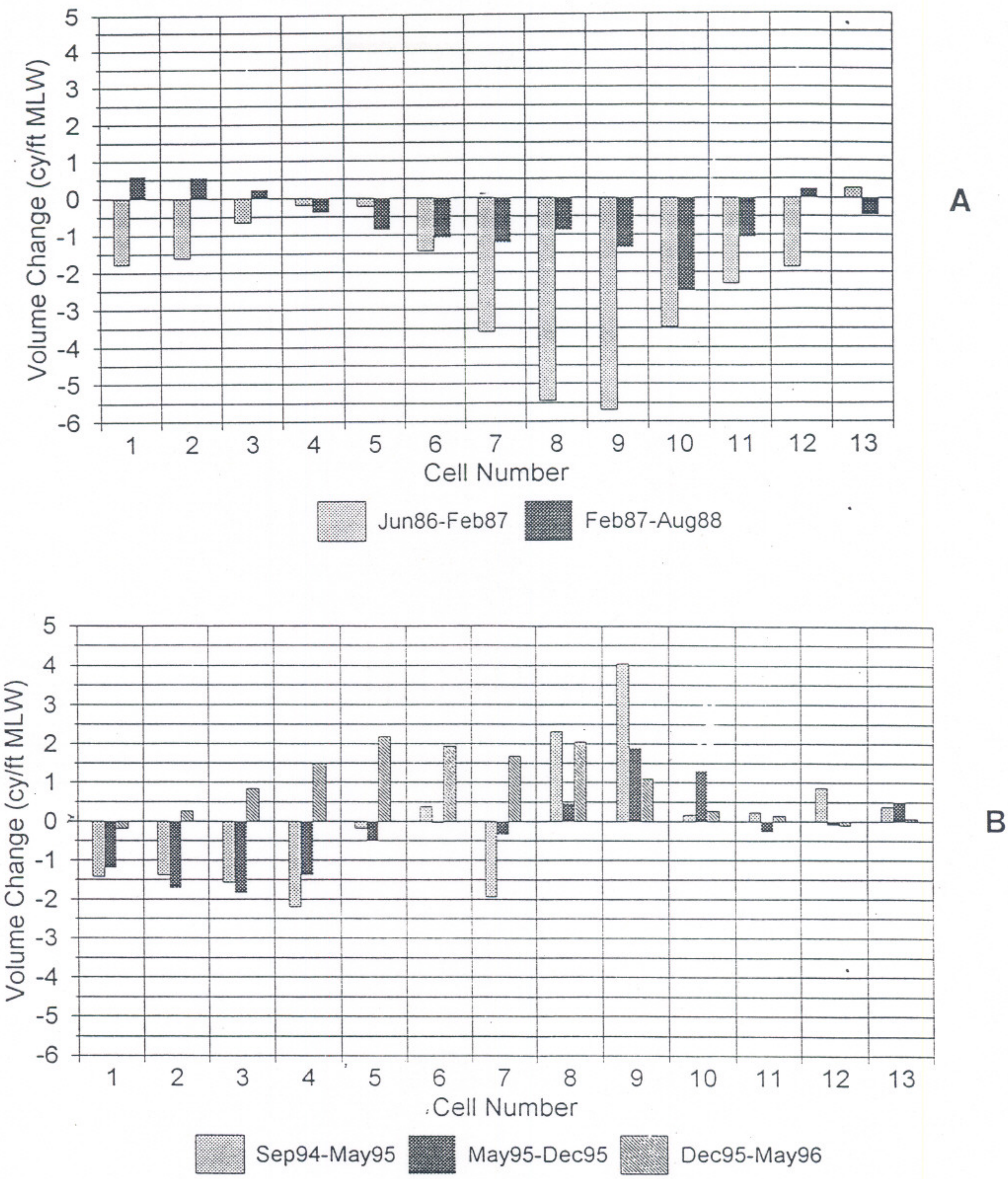


Figure 16. Subaerial beach volume change after A.) the 1986 small breakwater and fill project and B.) the 1994 Shoreline Erosion Control project.

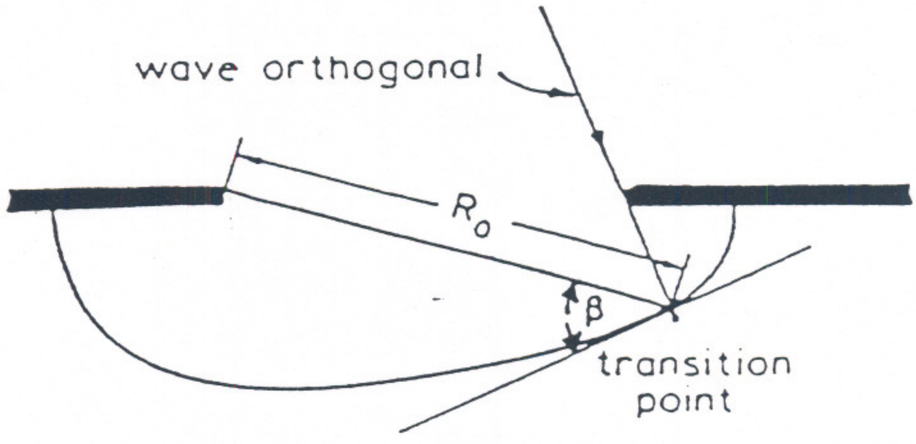
V. Shore Project: 1994

The Yorktown Waterfront Shore Erosion Control and Beach Restoration Plan (VHB, 1993) details the design processes that led to the shore erosion control project that was finally installed in the summer of 1994. The initial concept was developed in 1988\1989 by York County personnel with input from VIMS. Basically, a system of breakwaters and beach were desired to create a stable and protective recreational beach along the Yorktown waterfront. The beach design for the project was developed with VIMS Shoreline Studies under contract from Vanesse Hangin and Brustlin (VHB) to establish the local wave climate and its relationship to expected beach planform configuration.

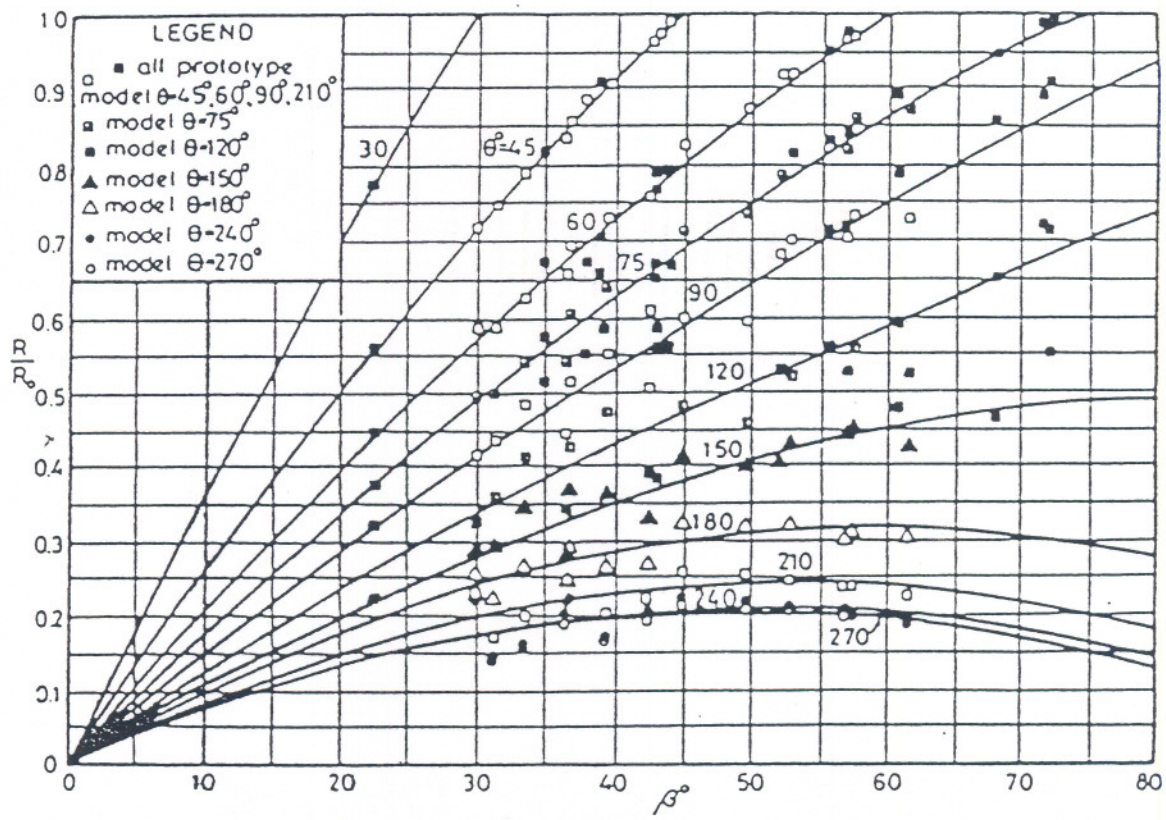
In evaluating design alternatives, the beach planforms of the pocket beach was calculated using procedures developed by Hsu *et al*. 1989 (Figure 17). By using a wave approach angle of 65° TN (bearing 245°TN), from wave analysis, across the downriver end of the upriver breakwater, the maximum indentation of the spiral portion of the beach planform, values of Ro, beta, theta and R/Ro were determined. When plotted out, the general planform is created. This computational method is most appropriately applied on breakwater systems that have a gap greater than two times the significant wave length.

The final design is shown in Figure 18. The existing small breakwater is left in its present location, thereby, eliminating the need to extend the storm sewer and encroach toward submerged cultural resources (i.e. shipwrecks). The existing small breakwater was extended upriver and angled offshore to move the diffraction point out and bring the structure in line with the downriver end of the new large breakwater. The large straight breakwater is angled to address the northeast component and move the upstream diffraction point offshore to insure stability of the primary embayment. The tangential section of the primary bay mimics the orientation of the existing pocket beaches just downriver of the project. These pocket beaches face between 60° and 70° TN (bearing 240° and 250° TN). The small embayment between the large breakwater and the existing small breakwater is symmetrical and very stable due to the small gap.

Several features of the upstream breakwater (near the bathhouse) are noteworthy. As shown in Figure 18, the structure is angular to address the dominant wave conditions at the site. The downstream end of the structure has been angled to the northeast to insure stability of the primary embayment. Under sediment transport conditions generated by easterly or northeasterly waves, sediment will perch on the downstream side of the structure, without bypassing around the end, or



Static equilibrium bay determination of R_o + B.



Empirical relationships for static equilibrium bays.

Figure 17. Equilibrium bay computation graphic and computation variables (after Hsu *et al.*, 1989).

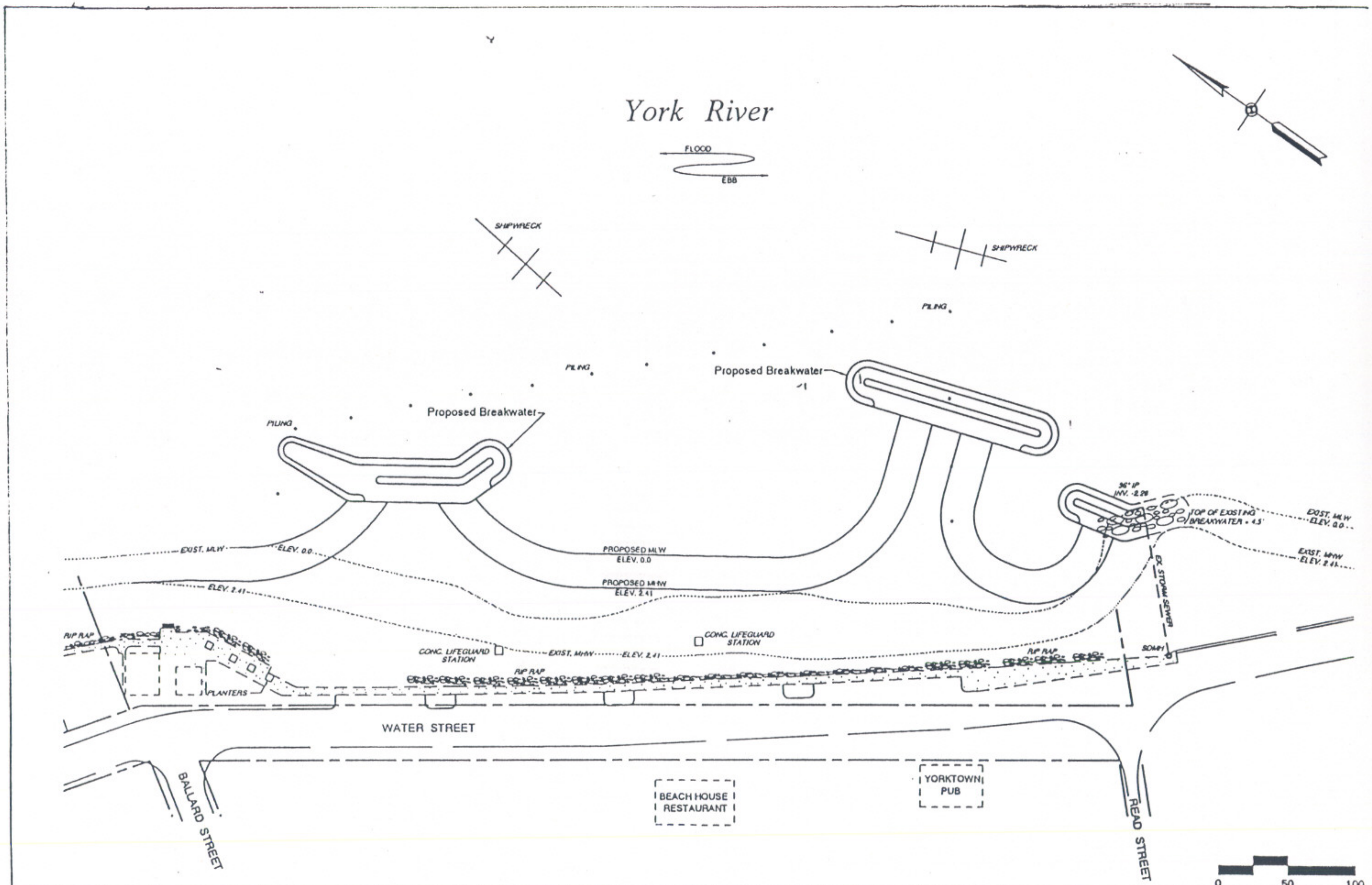
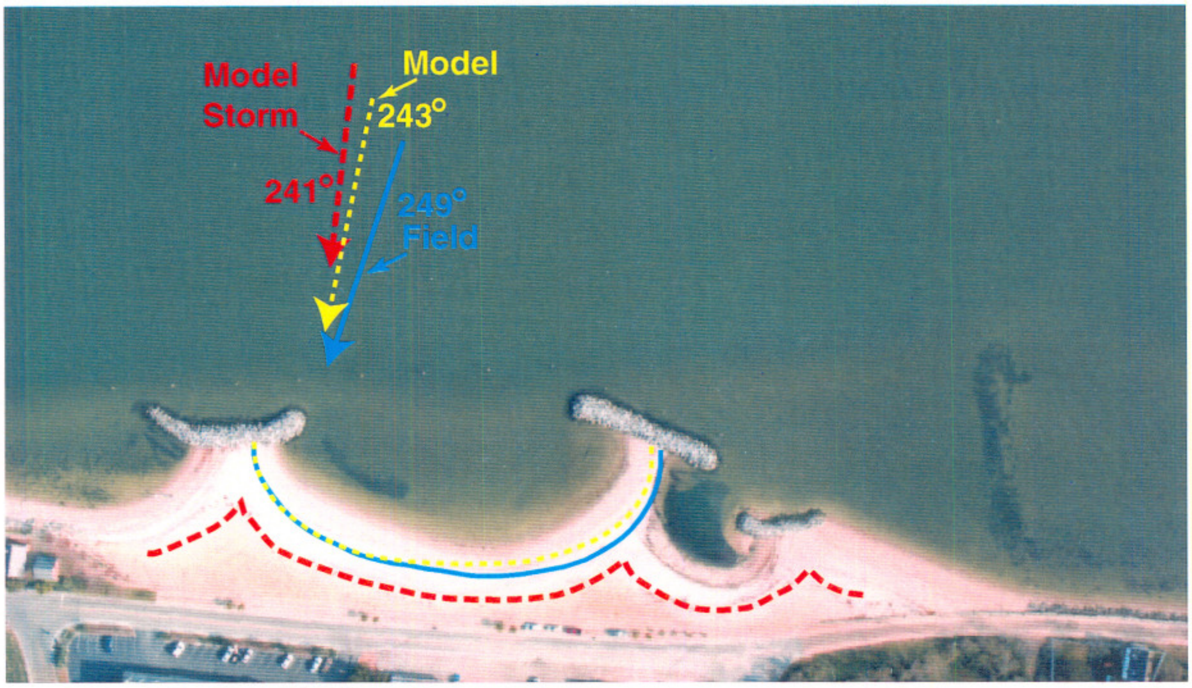


Figure 18. Yorktown Beach 1994 Shoreline Erosion Control project final design.

moving offshore. This retains the sand within the primary embayment, maintaining a reserve for shoreline shifts forced by northwesterly waves. The long term goal is to maintain a substantial beach berm with a relatively high backshore elevation of +6 ft MLW (VHB, 1993).

The other (upstream side) side of the upstream breakwater was angled into the northwest direction. This will allow a beach to perch on the upstream side of the structure during northwesterly wind/wave events. This perched beach will provide a sand reserve for transport under northeasterly wave conditions. In addition, the crest elevation of the breakwater has been dropped on the upstream end to prevent total wave diffraction under strong northeasterly storm events that occur at super-elevated tides. The intent was to reduce storm impacts on the upstream shoreline, from the bath house to the Post Office, by allowing approaching waves to more subtly refract, rather than diffract at the breakwater. It must be noted that this project was a first phase of a more comprehensive plan that includes a large pier extending downriver of the Post Office wharf. This pier will have its own modifying impact to Yorktown Beach.

The performance of the 1994 shoreline project is measured in the stability of the primary embayment. Figure 19A shows the project shortly after installation along with model (RCPWAVE) wave vectors and corresponding predicted beach planforms for storm and seasonal conditions. The field wave vector is predicted from the shape of the beach at that time and fits very well with the model predictions. The model storm condition is for a +5 ft MLW surge across the backshore which also fits well with beach planform performance over time (Figure 19B and 19C). Figure 19C also shows the addition of 600 cy (460 m^3) of sand along the shoreline of the primary bay. The sand was obtained from the Coleman Bridge construction.



Yorktown 9 Dec 94

Yorktown 2 Oct 95

Yorktown 11 May 96

Figure 19. Aerial photos of the project on A.) 9 Dec 1994, B.) 2 Oct 1995, and C.) 11 May 1996, 1"= 200'.

VI. SUMMARY AND CONCLUSIONS

The Yorktown Public Beach has had a recent history of severe erosion, property damage and beach loss. Open fetch exposure to the east and northeast results in a relatively severe wave climate by Chesapeake Bay standards. The 1986 beach project, which was the result of damage from the November 1985 storm, restored the beach and provided a very usable and clean beach area for the citizens of York County and the surrounding area. As that beach eroded away, the defensive revetment performed as designed to maintain upland protection.

The 1994 beach project was installed to restore the beach again but with two large breakwaters to maintain the beach nourishment element. This project, Phase I of an overall shoreline plan by York County, has performed very well and the beach planform of the primary embayment resides in the predicted configuration. The flooding of Water Street is still a problem, but there are no waves breaking on the road, as witnessed in previous storms, due to the protective beach and breakwater system.

VII. RECOMMENDATIONS

Phase II of York County's shoreline plan for Yorktown is currently in the design stage. Our recommendations to that effort include addressing long term stability of the beach area from the Post Office to the bath house. The preliminary shoreline plan indicates construction of a large pier to accommodate cruise ships. This pier will act to attenuate wave action against that section of beach and maybe all that is required for stability. If the pier is not built or not built in the near future, other options should be investigated. This may include placing a spur and/or breakwater just offshore in order to reduce sediment movement. The addition of beach fill to that scenario is also recommended.

Water Street is still flooded under moderate storm attack. The backshore should be raised along that section of beach which is about the middle of the primary embayment. This approach was suggested previously and is part of the Phase II design. A concrete "backstop" can be placed just seaward of the existing sidewalk to allow the backshore to reside against at a higher elevation. This would reduce flooding and keep beach sand from being washed onto Water Street.

VIII. REFERENCES

Anderson, G.L., G.B. Williams, M.H. Peoples, P. Rosen, and C.H. Hobbs, III, 1975. *Shoreline Situation Report, York County, Virginia.* SRAMSOE No. 82. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia, 62 pp.

Bascom, W.N., 1959. The relationship between sand size and beach face slope. *Am. Geophys. Union Transactions* 32(6):866-874.

Boon, J.D., C.S. Welch, H.S. Chen, R.J. Lukens, C.S. Fang, and J.M. Zeigler, 1978. *A Storm Surge Model Study, Vol. I. Storm Surge Height-Frequency Analysis and Model Prediction for Chesapeake Bay.* SRAMSOE No. 189. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia, 149 pp + app.

Boon, J.D., D.A. Hepworth, and F.H. Farmer, 1992. Chesapeake Bay Wave Climate, Wolf Trap Wave Station. Data Report No. 42. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA, 30 pp. +app.

Bretschneider, C.L., 1952. The generation and decay of wind waves in deep water. *Transactions of the American Geophysical Union*, **33**: 381-389.

Bretschneider, C.L., 1958. Revisions in wave forecasting: Deep and shallow water. Proceedings Sixth Conf. on Coastal Engineering, ASCE, Council on Wave Research.

Byrne, R.J. and G.L. Anderson, 1978. *Shoreline Erosion in Tidewater Virginia.* SRAMSOE No. 111. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia, 102 pp.

Ebersole, B.A., M.A. Cialone, and M.D. Prater, 1986. *RCPWAVE - A Linear Wave Propagation Model for Engineering Use.* CERC-86-4, U.S. Army Corps of Engineers Report, 260 pp.

Folk, R.L., 1980. Petrology of Sedimentary Rocks. Hemphill Publishing Co., Austin TX, 182 pp.

Friedman, G.M. and J.E. Sanders, 1978. Principles of Sedimentology. John Wiley and Sons, New York, 792 pp.

Hardaway, C.S., Jr., G.R. Thomas, and J.H. Li, 1991. *Chesapeake Bay Shoreline Studies: Headland Breakwaters and Pocket Beaches for Shoreline Erosion Control*. SRAMSOE No. 313, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA, 153 pp.

Hardaway, C.S., Jr., D.A. Milligan and G.R. Thomas, 1993. *Public Beach Assessment Report: Cape Charles Beach, Town of Cape Charles, Virginia*. Technical Report, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA, 42 pp. + app.

Hsu J.R.C., R. Silvester and Y.M. Xia, 1989. Generalities on static equilibrium bays. *Coastal Engineering*, **12**: 353-369.

Kiley, K., 1982. Estimates of bottom water velocities associated with gale wind generated waves in the James River, Virginia. Virginia Institute of Marine Science, School of Marine Science, College of William and Mary, Gloucester Point, VA.

Komar, P.D., 1976. *Beach Processes and Sedimentation*. Prentice-Hall, Inc., Englewood Cliffs, NJ, 429 pp.

Milligan, D.A., C.S. Hardaway, Jr., and G.R. Thomas, 1995. *Public Beach Assessment Report: Huntington Park Beach, Anderson Park Beach, and King-Lincoln Park Beach, City of Newport News, Virginia.* Technical Report, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA, 60 pp. + app.

Rosen, P.S., 1976. *The Morphology and Processes of the Virginia Chesapeake Bay Shoreline*. Unpublished Dissertation. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA.

Stauble, D.K., A.W. Garcia, N.C. Kraus, W.G. Grosskopf, and G.P. Bass, 1993. *Beach Nourishment Project Response and Design Evaluation: Ocean City, Maryland*. Technical Report CERC-93-13, Coastal Engineering Research Center, U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.

Suh, K.D, 1990. *WINDOW* Program. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia.

Sverdrup, H.U. and W.H. Munk, 1947. Wind sea, and swell: Theory of relations for forecasting. U.S. Navy Hydrographic Office Publ. No. 601.

Tidelog, 1996. Chesapeake Tidewater. Pacific Publishers, Bolinas, CA.

U.S. Army Corps of Engineers, 1977. *Shore Protection Manual*. Coastal Engineering Research Center, Fort Belvoir, Virginia.

U.S. Army Corps of Engineers, 1984. *Shore Protection Manual*. U.S. Government Printing Office, Washington, D.C.

U.S. Army Corps of Engineers, 1989. Yorktown Beach, Yorktown, Virginia. Draft Section 933 Evaluation Report. Norfolk District, 20 pp. +app.

U.S. Army Corps of Engineers, 1993. *Shoreline Erosion Study, Fort Eustis, Virginia.* Norfolk District.

VHB, 1993. *Yorktown Waterfront Shore Erosion Control and Beach Restoration Plan, Yorktown, Virginia*. Permit Support Document, Vanasse Hangen Brustlin, Inc., Gloucester County, Virginia. 24 pp +app.

Wright, L.D., C.S. Kim, C.S. Hardaway, Jr., S.M. Kimball, and M.O. Green, 1987. *Shoreface and Beach Dynamics of the Coastal Region from Cape Henry to False Cape, Virginia.* Technical Report, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia, 116 pp.

APPENDIX I

Yorktown Public Beach Sediment Data

Yorktown					Sample Analysis					RSA results - Sand portion				
Date	Number	Location	% gravel	%sand	%silt	%clay	%mud	Mean	Mean	Median	Median	Sorting	Skewness	Kurtosis
								(phi)	(mm)	(phi)	(mm)	(phi)		
15 Aug 1988	1-1	BOR	11.6	87.4	1.0	0.0	1.0	0.6403	0.6416	0.6590	0.6333	0.5748	0.0022	0.7610
15 Aug 1988	1-2	BERM	3.2	96.2	0.6	0.0	0.6	0.7182	0.6079	0.7695	0.5866	0.5697	-0.1171	0.7500
15 Aug 1988	1-3	LHT	8.3	91.1	0.6	0.0	0.6	1.0482	0.4836	1.1000	0.4665	0.5355	-0.1578	0.6857
15 Aug 1988	1-4		19.3	79.9	0.8	0.0	0.8	0.5087	0.7029	0.5656	0.6757	0.5744	-0.0976	0.9282
15 Aug 1988	1-5	OS	34.3	64.8	0.9	0.0	0.9	0.7706	0.5862	0.8391	0.5590	0.7120	-0.1155	0.9152
15 Aug 1988	3-1		20.5	79.0	0.5	0.0	0.5	0.6271	0.6475	0.6850	0.6220	0.7185	-0.0715	0.8421
15 Aug 1988	3-2		10.6	88.8	0.6	0.0	0.6	0.8799	0.5434	0.9465	0.5189	0.6915	-0.1815	0.9953
15 Aug 1988	3-3	LHT	2.6	96.7	0.7	0.0	0.7	0.9322	0.5241	1.0065	0.4978	0.6021	-0.2130	0.8757
15 Aug 1988	3-4	MB	12.9	86.0	1.0	0.0	1.0	0.3205	0.8008	0.2789	0.8242	0.6088	0.2154	1.2973
15 Aug 1988	3-5	OS	51.5	47.4	1.1	0.0	1.1	0.7385	0.5994	0.8137	0.5689	0.7270	-0.1765	0.9432
15 Aug 1988	5-1		34.0	64.8	1.2	0.0	1.2	0.8133	0.5691	0.8673	0.5482	0.6728	-0.1384	0.8225
15 Aug 1988	5-2		10.5	89.0	0.5	0.0	0.5	0.8770	0.5445	0.9123	0.5313	0.6233	-0.1626	0.8074
15 Aug 1988	5-3		1.8	97.4	0.8	0.0	0.8	1.0872	0.4707	1.0986	0.4670	0.4911	-0.0183	0.7413
15 Aug 1988	5-4		3.6	95.3	1.1	0.0	1.1	0.6910	0.6194	0.7209	0.6067	0.5544	-0.0506	0.8886
15 Aug 1988	5-5		2.7	95.6	1.7	0.0	1.7	1.0693	0.4766	1.0662	0.4776	0.6800	0.0238	0.7940
15 Aug 1988	7-1		16.8	82.4	0.8	0.0	0.8	0.8558	0.5526	0.9382	0.5219	0.6636	-0.1809	0.8094
15 Aug 1988	7-2		30.3	69.0	0.7	0.0	0.7	1.1212	0.4597	1.1387	0.4542	0.6942	-0.0506	0.6672
15 Aug 1988	7-3		13.2	86.0	0.8	0.0	0.8	1.1007	0.4663	1.1068	0.4643	0.4934	-0.0354	0.6855
15 Aug 1988	7-4		13.9	84.9	1.2	0.0	1.2	0.4779	0.7180	0.5233	0.6958	0.5878	-0.0273	1.2101
15 Aug 1988	7-5		16.2	81.6	2.2	0.0	2.2	1.1094	0.4635	1.0925	0.4689	0.6853	0.0727	0.8031
15 Aug 1988	9-1		5.8	92.3	2.0	0.0	2.0	0.9458	0.5191	0.9583	0.5147	0.8149	-0.0571	0.9896
15 Aug 1988	9-2		4.6	94.1	1.3	0.0	1.3	0.8460	0.5563	0.8190	0.5668	0.6365	0.0683	0.8523
15 Aug 1988	9-3		20.7	78.4	0.9	0.0	0.9	0.3758	0.7707	0.4344	0.7400	0.6368	-0.0148	1.3632
15 Aug 1988	9-4		62.2	36.1	1.6	0.0	1.6	0.9717	0.5099	0.9975	0.5009	0.8879	-0.0494	0.8662
15 Aug 1988	9-5		9.2	87.7	3.1	0.0	3.1	1.3604	0.3895	1.2872	0.4097	0.8833	0.0784	0.7055
15 Aug 1988	11-1		10.2	88.1	1.7	0.0	1.7	0.9249	0.5267	0.9591	0.5144	0.7452	-0.0821	0.8257
15 Aug 1988	11-2		22.5	76.0	1.5	0.0	1.5	0.7710	0.5860	0.7520	0.5938	0.7799	0.1002	0.8831
15 Aug 1988	11-3	BBW	22.3	76.4	1.3	0.0	1.3	0.3545	0.7821	0.3231	0.7994	0.5995	0.0979	0.9831
15 Aug 1988	13-1		10.2	89.1	0.7	0.0	0.7	1.0781	0.4737	1.0769	0.4740	0.5739	-0.0099	0.7300
15 Aug 1988	13-2		0.9	98.0	1.1	0.0	1.1	1.9023	0.2675	1.9070	0.2666	0.4680	-0.0051	0.3986
15 Aug 1988	13-3		21.4	77.4	1.2	0.0	1.2	0.7762	0.5839	0.7363	0.6003	0.5987	0.1677	0.8222
15 Aug 1988	13-4		18.3	80.6	1.1	0.0	1.1	0.4860	0.7140	0.4891	0.7125	0.7628	0.1075	1.3907
15 Aug 1988	13-5		25.8	71.4	2.9	0.0	2.9	1.5124	0.3505	1.4801	0.3585	0.9480	-0.0324	0.7015

Yorktown					Sample Analysis					RSA results - Sand portion				
Date	Number	Location	% gravel	%sand	%silt	%clay	%mud	Mean (phi)	Mean (mm)	Median (phi)	Median (mm)	Sorting (phi)	Skewness	Kurtosis
5 MAY 1994	3-1	BS	2.69	96.77	0.31	0.22	0.5	1.0072	0.4975	1.2646	0.4162	0.7203	-0.3479	0.8348
5 MAY 1994	3-2	LHT	0.00	99.31	0.69	0.00	0.7	1.5275	0.3469	1.5844	0.3335	0.6169	-0.1315	0.7841
5 MAY 1994	3-3	MB	26.56	72.87	0.56	0.00	0.6	0.4400	0.7371	0.3389	0.7906	0.6372	0.3536	1.2548
5 MAY 1994	3-4	TOE	25.76	73.72	0.52	0.00	0.5	0.7245	0.6052	0.6482	0.6381	0.7397	0.0962	1.2600
5 MAY 1994	3-5	OS	2.56	97.21	0.22	0.00	0.2	1.2703	0.4146	1.2803	0.4117	0.5927	0.0573	0.7253
5 MAY 1994	7-1	BOR	0.00	99.30	0.00	0.70	0.7	0.5849	0.6667	0.5610	0.6778	0.3577	0.0985	0.7819
5 MAY 1994	7-2	MB	6.20	93.10	0.00	0.70	0.7	0.7241	0.6054	0.6509	0.6369	0.5465	0.1824	0.7827
5 MAY 1994	7-3	TOE	10.50	88.60	0.00	0.80	0.8	0.5064	0.7040	0.4818	0.7161	0.5183	0.0907	1.0842
5 MAY 1994	7-4	OS	1.40	97.50	0.00	1.10	1.1	1.4468	0.3668	1.4252	0.3724	0.7269	0.1177	0.8320
5 MAY 1994	10-1	TR	10.45	89.22	0.33	0.00	0.3	1.4024	0.3783	1.3978	0.3795	0.5838	0.0823	0.6572
5 MAY 1994	10-2	BERM	0.00	99.78	0.22	0.00	0.2	1.7420	0.2990	1.7253	0.3024	0.3736	0.1410	0.4353
5 MAY 1994	10-3	MB	8.14	90.98	0.00	0.88	0.9	0.8440	0.5571	0.8333	0.5612	0.4169	0.0947	0.5927
5 MAY 1994	10-4	TOE	3.32	96.36	0.03	0.30	0.3	1.0273	0.4906	1.0462	0.4842	0.6670	0.2191	1.3852
5 MAY 1994	10-5	OS	0.00	96.74	0.50	2.76	3.3	2.0286	0.2451	2.5744	0.1679	1.3511	-0.5205	0.6161
5 MAY 1994	13-1	BS	22.64	77.26	0.00	0.10	0.1	1.1722	0.4437	1.1460	0.4519	0.5278	0.2413	0.7989
5 MAY 1994	13-2	LHT	4.47	93.84	0.00	1.68	1.7	1.5138	0.3502	1.4494	0.3662	0.8920	0.1434	0.8371
5 MAY 1994	13-3	MB	23.40	76.27	0.00	0.33	0.3	0.8120	0.5696	0.5909	0.6639	0.8711	0.3682	0.9290
5 MAY 1994	13-4	TOE	12.00	86.96	0.00	1.04	1.0	0.5601	0.6783	0.4724	0.7208	0.8524	0.3739	1.4084
5 MAY 1994	13-5	OS	2.76	95.66	0.79	0.79	1.6	1.4550	0.3648	1.4644	0.3624	0.8812	0.0550	0.6341

Yorktown					Sample Analysis					RSA results - Sand portion				
Date	Number	Location	% gravel	%sand	%silt	%clay	%mud	Mean	Mean	Median	Median	Sorting	Skewness	Kurtosis
								(phi)	(mm)	(phi)	(mm)	(phi)		
2 Sep 1994	3-1	BS	6.38	91.22	1.18	1.22	2.39	1.6343	0.3221	1.6572	0.3171	0.7691	0.0014	0.6975
2 Sep 1994	3-2	LHT	10.12	89.60	0.00	0.28	0.28	1.8755	0.2725	1.9040	0.2672	0.5770	-0.1014	0.5148
2 Sep 1994	3-3	MD	0.00	99.98	0.00	0.02	0.02	1.5892	0.3324	1.6406	0.3207	0.6968	-0.1268	0.6508
2 Sep 1994	3-4	TOE	51.62	48.30	0.09	0.00	0.09	1.0170	0.4941	0.9350	0.5230	0.8818	0.1560	0.9881
2 Sep 1994	3-5	OS	6.35	92.99	0.57	0.09	0.66	1.4383	0.3690	1.4172	0.3744	0.6822	0.1223	0.7486
2 Sep 1994	7-1	BERM	4.50	91.50	0.90	3.10	4.00	1.1749	0.4429	1.2116	0.4318	0.8054	-0.0385	0.8054
2 Sep 1994	7-2	LHT	2.30	96.70	0.40	0.60	1.00	1.4567	0.3643	1.5588	0.3394	0.6583	-0.1865	0.5756
2 Sep 1994	7-3	MB	0.40	98.50	0.00	1.10	1.10	1.3159	0.4017	1.2867	0.4099	0.6642	0.0643	0.6762
2 Sep 1994	7-4	TOE	3.40	95.30	0.00	1.30	1.30	0.8283	0.5632	0.8862	0.5410	0.6827	-0.0524	0.8019
2 Sep 1994	7-5	OS	1.20	87.80	4.20	6.80	11.00	1.4581	0.3640	1.4711	0.3607	0.6786	0.0278	0.7523
2 Sep 1994	10-1	BERM	10.63	88.52	0.84	0.00	0.84	1.2631	0.4166	1.1575	0.4483	0.7789	0.2828	0.7380
2 Sep 1994	10-2	LHT	3.19	95.32	0.84	0.65	1.48	1.6640	0.3156	1.7063	0.3064	0.8464	-0.0815	0.6392
2 Sep 1994	10-3	MB	3.31	95.05	0.00	1.63	1.63	2.0572	0.2403	2.1117	0.2314	0.7448	-0.0945	0.5369
2 Sep 1994	10-4	TOE	6.71	93.29	0.00	0.00	0.00	1.1393	0.4540	1.0248	0.4915	0.8933	0.1841	0.8114
2 Sep 1994	10-5	OS	25.34	73.31	1.36	0.00	1.36	0.8638	0.5495	0.6785	0.6248	0.9712	0.3807	1.0003
2 Sep 1994	13-1	BS	1.75	97.84	0.78	0.00	0.78	1.0643	0.4782	1.0071	0.4975	0.6424	0.2303	0.6956
2 Sep 1994	13-2	LHT	0.00	100.00	0.00	0.00	0.00	1.1012	0.4661	1.0331	0.4887	0.5672	0.2681	0.7130
2 Sep 1994	13-3	MB	0.00	99.54	0.00	0.46	0.46	1.5005	0.3534	1.4129	0.3756	0.6402	0.2582	0.6193
2 Sep 1994	13-4	TOE	14.77	85.31	0.00	0.00	0.00	0.9095	0.5324	0.7485	0.5952	0.7529	0.4412	0.9227
2 Sep 1994	13-5	OS	10.88	87.66	1.46	0.00	1.46	2.5511	0.1706	2.7324	0.1505	0.8850	-0.2609	0.5313

Yorktown					Sample Analysis					RSA results - Sand portion				
Date	Number	Location	% gravel	%sand	%silt	%clay	%mud	Mean	Mean	Median	Median	Sorting	Skewness	Kurtosis
								(phi)	(mm)	(phi)	(mm)	(phi)		
16 May 1995	3-1	BS	14.36	84.09	0.73	0.81	1.5	1.2470	0.4213	1.2678	0.4153	0.4709	-0.0600	0.5602
16 May 1995	3-2	LHT	21.91	77.37	0.72	0.00	0.7	1.0801	0.4730	1.0834	0.4719	0.8568	0.1391	1.2759
16 May 1995	3-3	MB	7.01	90.02	2.61	0.36	3.0	1.2970	0.4070	1.3200	0.4005	0.7353	-0.0066	0.7266
16 May 1995	3-4	TOE	44.16	54.37	0.42	1.05	1.5	1.4854	0.3571	1.5103	0.3510	0.8193	-0.0314	0.6877
16 May 1995	3-5	OS	25.40	71.27	2.11	1.22	3.3	1.5085	0.3515	1.4301	0.3711	0.6615	0.2026	0.6988
16 May 1995	7-1	BS	1.60	96.50	0.30	1.60	1.9	1.4632	0.3627	1.4877	0.3566	0.6013	-0.0381	0.6715
16 May 1995	7-2	LHT	0.90	98.60	0.00	0.50	0.5	1.1869	0.4392	1.2015	0.4348	0.5515	-0.1229	0.7133
16 May 1995	7-3	MB	3.80	95.40	0.60	0.20	0.8	0.8942	0.5380	0.9105	0.5320	0.6427	0.0455	0.8031
16 May 1995	7-4	TOE	5.50	93.30	0.10	1.10	1.2	0.8638	0.5495	0.9011	0.5355	0.6319	-0.0995	0.8459
16 May 1995	7-5	OS	3.10	92.40	0.90	3.70	4.6	1.6170	0.3260	1.5605	0.3390	0.6074	0.1313	0.6029
16 May 1995	10-1	BS	6.00	93.43	0.00	0.57	0.6	1.2811	0.4115	1.2421	0.4228	0.8794	0.1584	0.9068
16 May 1995	10-2	LHT	3.23	96.20	0.36	0.20	0.6	1.0641	0.4783	0.8516	0.5542	0.6899	0.5618	0.9017
16 May 1995	10-3	MB	5.89	93.47	0.00	0.64	0.6	1.4583	0.3639	1.3872	0.3823	0.9077	0.1334	0.6013
16 May 1995	10-4	TOE	26.71	69.54	2.97	0.78	3.8	1.3500	0.3923	1.1152	0.4616	0.9789	0.3303	0.7586
16 May 1995	10-5	OS	0.00	97.01	0.00	2.99	3.0	2.8138	0.1422	3.0361	0.1219	0.7475	-0.5010	0.4909
16 May 1995	13-1	BS	0.00	98.63	0.90	0.46	1.4	0.8892	0.5399	0.7777	0.5833	0.6135	0.4151	0.9530
16 May 1995	13-2	LHT	0.00	99.27	0.53	0.20	0.7	1.3294	0.3979	1.2943	0.4077	0.5903	0.1540	0.7128
16 May 1995	13-3	MB	7.98	90.61	0.20	1.20	1.4	1.6811	0.3118	1.7426	0.2988	0.8508	-0.0485	0.5789
16 May 1995	13-4	TOE	12.59	86.84	0.00	0.57	0.6	1.1803	0.4413	1.1317	0.4564	0.7413	0.1617	0.8269
16 May 1995	13-5	OS	1.78	95.26	2.02	0.93	3.0	1.9532	0.2582	2.0839	0.2359	0.8503	-0.2089	0.5117

Yorktown					Sample Analysis					RSA results - Sand portion				
Date	Number	Location	% gravel	%sand	%silt	%clay	%mud	Mean	Mean	Median	Median	Sorting	Skewness	Kurtosis
								(phi)	(mm)	(phi)	(mm)	(phi)		
18 Dec 1995	3-1	BS	0.00	99.72	0.00	0.28	0.3	1.6722	0.3138	1.6567	0.3172	0.3778	0.2067	0.4955
18 Dec 1995	3-2	LHT	0.00	99.04	0.12	0.84	1.0	1.3290	0.3980	1.3483	0.3928	0.3729	-0.0209	0.4405
18 Dec 1995	3-3	MB	49.79	49.71	0.00	0.50	0.5	1.1040	0.4652	1.1825	0.4406	0.8511	-0.0397	0.7855
18 Dec 1995	3-4	TOE	58.39	41.61	0.00	0.00	0.0	1.0819	0.4724	1.0551	0.4813	1.0307	0.1186	0.8570
18 Dec 1995	3-5	OS	46.78	52.28	0.00	0.94	0.9	1.3862	0.3826	1.3571	0.3904	0.7730	0.1691	0.8367
18 Dec 1995	7-1	BS	7.23	91.87	0.00	0.90	0.9		1.0000		1.0000			
18 Dec 1995	7-2	LHT	16.51	83.39	0.09	0.00	0.1		1.0000		1.0000			
18 Dec 1995	7-3	MB	5.38	93.99	0.00	0.64	0.6		1.0000		1.0000			
18 Dec 1995	7-4	TOE	9.47	90.53	0.00	0.00	0.0		1.0000		1.0000			
18 Dec 1995	7-5	OS	20.55	79.03	0.00	0.42	0.4		1.0000		1.0000			
18 Dec 1995	10-1	BS	7.46	91.48	0.00	1.07	1.1	1.6470	0.3193	1.6016	0.3295	0.8105	0.1675	0.7387
18 Dec 1995	10-2	LHT	0.00	98.95	1.05	0.00	1.1		1.0000		1.0000			
18 Dec 1995	10-3	MB	0.00	97.31	2.57	0.12	2.7		1.0000		1.0000			
18 Dec 1995	10-4	TOE	10.57	83.62	5.80	0.00	5.8		1.0000		1.0000			
18 Dec 1995	10-5	OS	0.00	94.88	5.12	0.00	5.1		1.0000		1.0000			
18 Dec 1995	13-1	BS	0.00	95.16	4.84	0.00	4.8		1.0000		1.0000			
18 Dec 1995	13-2	LHT	0.00	99.10	0.00	0.90	0.9		1.0000		1.0000			
18 Dec 1995	13-3	MB	4.56	95.16	0.00	0.28	0.3		1.0000		1.0000			
18 Dec 1995	13-4	TOE	16.91	82.63	0.00	0.46	0.5		1.0000		1.0000			
18 Dec 1995	13-5	OS	0.00	99.44	0.00	0.56	0.6		1.0000		1.0000			

Yorktown					Sample Analysis					RSA results - Sand portion				
Date	Number	Location	% gravel	%sand	%silt	%clay	%mud	Mean	Mean	Median	Median	Sorting	Skewness	Kurtosis
								(phi)	(mm)	(phi)	(mm)	(phi)		
13 May 1996	3-1	BS	9.13	90.65	0.21	0.00	0.2		1.0000		1.0000			
13 May 1996	3-2	LHT	0.00	98.94	0.00	1.06	1.1		1.0000		1.0000			
13 May 1996	3-3	MB	2.88	95.55	0.74	0.83	1.6		1.0000		1.0000			
13 May 1996	3-4	TOE	40.48	58.15	0.41	0.95	1.4		1.0000		1.0000			
13 May 1996	3-5	OS	2.79	97.21	0.00	0.00	0.0		1.0000		1.0000			
13 May 1996	7-1	BS	0.00	99.44	0.00	0.56	0.6		1.0000		1.0000			
13 May 1996	7-2	LHT	8.40	90.17	0.23	1.20	1.4		1.0000		1.0000			
13 May 1996	7-3	MB	53.90	45.37	0.00	0.73	0.7		1.0000		1.0000			
13 May 1996	7-4	TOE	28.44	71.03	0.53	0.00	0.5		1.0000		1.0000			
13 May 1996	7-5	OS	0.00	43.30	9.23	47.47	56.7		1.0000		1.0000			
13 May 1996	10-1	BS	0.00	95.66	4.34	0.00	4.3		1.0000		1.0000			
13 May 1996	10-2	LHT	19.51	60.22	0.00	0.27	0.3		1.0000		1.0000			
13 May 1996	10-3	MB	13.09	86.18	0.55	0.18	0.7		1.0000		1.0000			
13 May 1996	10-4	TOE	5.97	91.05	2.06	0.92	3.0		1.0000		1.0000			
13 May 1996	10-5	OS	0.00	99.98	0.00	0.02	0.0		1.0000		1.0000			
13 May 1996	13-1	BS	0.00	98.69	0.66	0.66	1.3		1.0000		1.0000			
13 May 1996	13-2	LHT	0.00	99.40	0.00	0.60	0.6		1.0000		1.0000			
13 May 1996	13-3	MB	14.83	84.36	0.81	0.00	0.8		1.0000		1.0000			
13 May 1996	13-4	TOE	12.95	86.49	0.38	0.18	0.6		1.0000		1.0000			
13 May 1996	13-5	OS	0.00	99.55	0.00	0.45	0.5		1.0000		1.0000			

APPENDIX II

Additional References about Littoral Processes and Hydrodynamic Modeling

Bagnold, R.A., 1963. Beach and nearshore processes; Part I: Mechanics of marine sedimentation. In M.N. Hill (ed.), *The Sea*, Vol. 3, Wiley-Interscience, pp. 507-528.

Bowen, A.J., D.L. Inman, and V.P. Simmons, 1968. Wave "set-down" and "set-up." *J. Geophys. Res.* 73:2569-2577.

Bretschneider, C.L. and R.O. Reid, 1954. Modification of wave height due to bottom friction, percolation and refraction. *Beach Erosion Board Tech. Memo*, No. 45.

Coastal Engineering Research Center, 1984. *Shore Protection Manual.* 4th ed., U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Christoffersen, J.B. and I.G. Jonsson, 1985. Bed-friction and dissipation in a combined current and wave motion. *Ocean Enginr.* 12(5):387-424.

Dally, W.R., R.G. Dean, and R.A. Dalrymple, 1984. Modelling wave transformation in the surf zone. *U.S. Army Engineer Waterways Experiment Station Misc. Paper*, CERC-84-8, Vicksburg, MS.

Dean, R.G., 1973. Heuristic models of sand transport in the surf zone. *Proceedings, Conf. Enginr. Dynamics in the Surf Zone*, Sydney, pp. 208-214.

Eaton, R.O., 1950. Littoral processes on sandy coasts. *Proceedings, 1st Intl. Conf. Coastal Enginr.*, pp. 140-154.

Grant, W.D. and O.S. Madsen, 1979. Combined wave and current interaction with a rough bottom. *J. Geophys. Res.* 84:1797-1808.

Grant, W.D. and O.S. Madsen, 1982. Movable bed roughness in unsteady oscillatory flow. *J. Geophys. Res.* 87:469-481.

Inman, D.L. and R.A. Bagnold, 1963. Beach and nearshore processes; Part II: Littoral processes. In M.N. Hill (ed.), *The Sea*, Vol. 3, Wiley-Interscience, pp. 529-553.

Jonsson, I.G., 1966. Wave boundary layers and friction factors. *Proceedings, 10th Intl. Conf. Coastal Enginr.*, pp. 127-148.

Kamphuis, J.W., 1975. Friction factor under oscillatory waves. ASCE, *J. Wat. Harb. Div.*, ASCE, 102(WW2):135-144.

Kinsman, B., 1965. *Wind Waves, Their Generation and Propagation on the Ocean Surface*. Dover, New York, 676 pp.

Komar, P.D., 1975. Nearshore currents: Generation by obliquely incident waves and longshore variations in breaker height. *Proceedings, Symp. Nearshore Sediment Dynamics*, Wiley, New York.

Komar, P.D., 1976. *Beach Processes and Sedimentation*. Prentice-Hall, New Jersey, 429 pp.

Komar, P.D., 1983. Nearshore currents and sand transport on beaches. In Johns (ed.), *Physical Oceanography of Coastal Shelf Seas*, Elsevier, New York, pp. 67-109.

Komar, P.D. and D.L. Inman, 1970. Longshore sand transport on beaches. *J. Geophys. Res.* 73(30):5914-5927.

Kraus, N.C. and T.O. Sasaki, 1979. Effects of wave angle and lateral mixing on the longshore current. *Coastal Enginr. in Japan* 22:59-74.

LeMehaute, B. and A. Brebner, 1961. An introduction to coastal morphology and littoral processes. *C.E. Research Report No. 14, Dept. of Civil Enginr.*, Queen's Univ., Kingston, Ontario.

Longuet-Higgins, M.S., 1972. Recent progress in the study of longshore currents. In R.E. Meyer (ed.), *Waves on Beaches and Resulting Sediment Transport*, Academic Press, New York, pp. 203-248.

Longuet-Higgins, M.S. and R.W. Stewart, 1962. Radiation stress and mass transport in gravity waves, with application to surf beats. *J. Fluid Mech.* 13:481-504.

Madsen, O.S., 1976. Wave climate of the continental margin: Elements of its mathematical description. In D.J. Stanley and D.J.P. Swift (eds.), *Marine Sediment Transport and Environmental Management*, Wiley, New York, pp. 65-90.

Munch-Peterson, J., 1938. Littoral drift formula. *Beach Erosion Board Bull.* 4(4):1-31.

Nielsen, P., 1983. Analytical determination of nearshore wave height variation due to refraction, shoaling and friction. *Coastal Enginr.* 7(3):233-252.

Savage, R.P., 1962. Laboratory determination of littoral transport rates. *J. WW and Harbours Div., ASCE* 88(WW2):69-92.

Weggel, J.R., 1972. Maximum breaker height. *J. WW and Harbours Div., ASCE* 78(WW4):529-548.

Wright, L.D., 1981. Beach cut in relation to surf zone morphodynamics. *Proceedings, 17th Intl. Conf. Coastal Enginr.*, Sydney, Australia, pp. 978-996.

Wright, L.D. and A.D. Short, 1984. Morphodynamic variability of surf zones and beaches: A synthesis. *Mar. Geol.* 56:93-118.

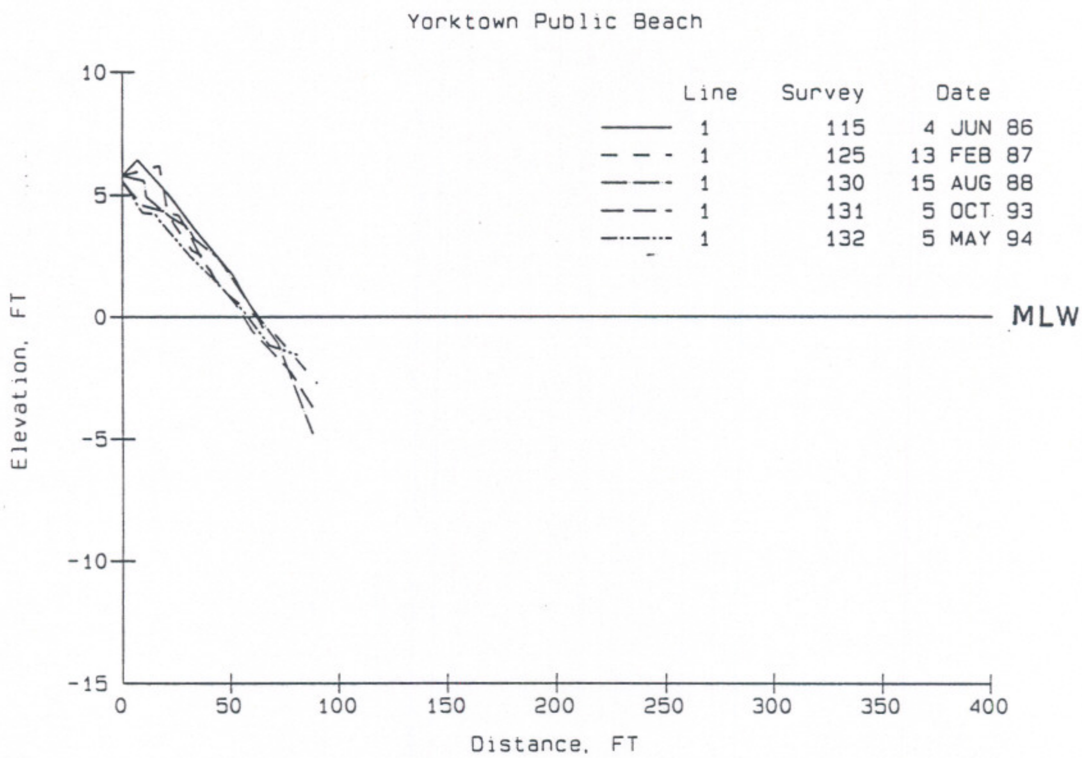
Wright, L.D., R.J. Guza, and A.D. Short, 1982. Dynamics of a high energy dissipative surfzone. *Mar. Geol.* 45:41-62.

Wright, L.D., A.D. Short, and M.O. Green, 1985. Short-term changes in the morphodynamic states of beaches and surfzones: An empirical predictive model. *Mar. Geol.* 62:339-364.

Wright, L.D., P. Nielsen, N.C. Shi, and J.H. List, 1986. Morphodynamics of a bar-trough surfzone. *Mar. Geol.* 70:251-285.

APPENDIX III

Yorktown Public Beach Profiles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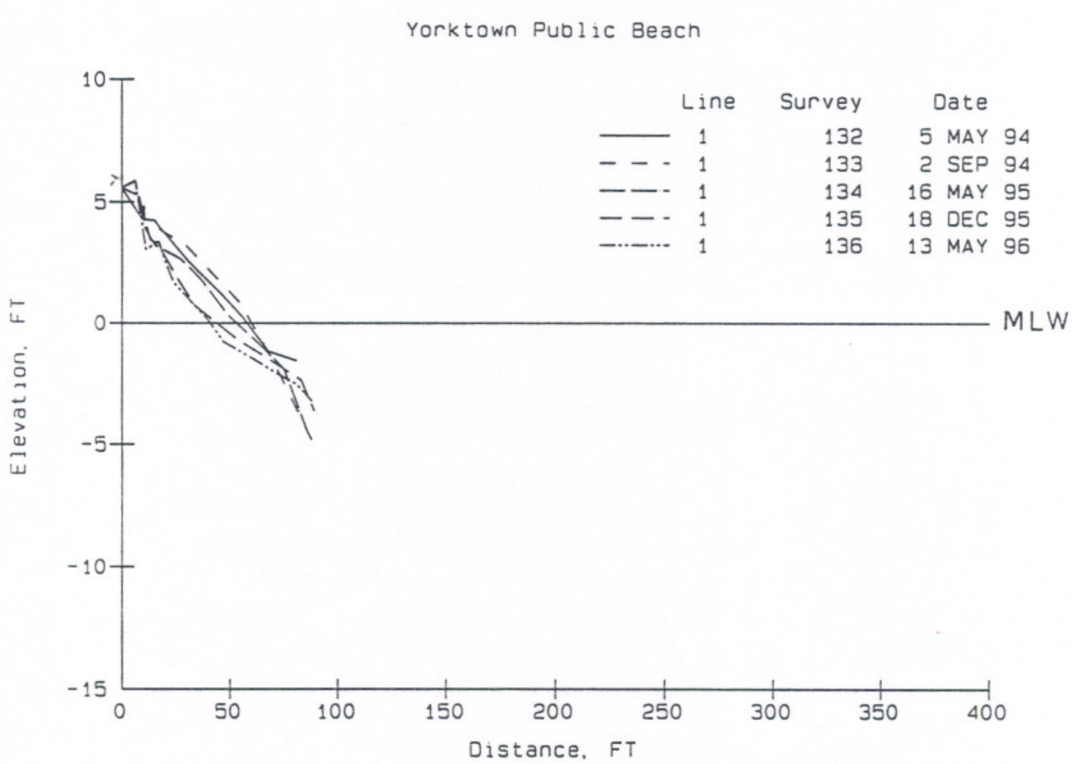
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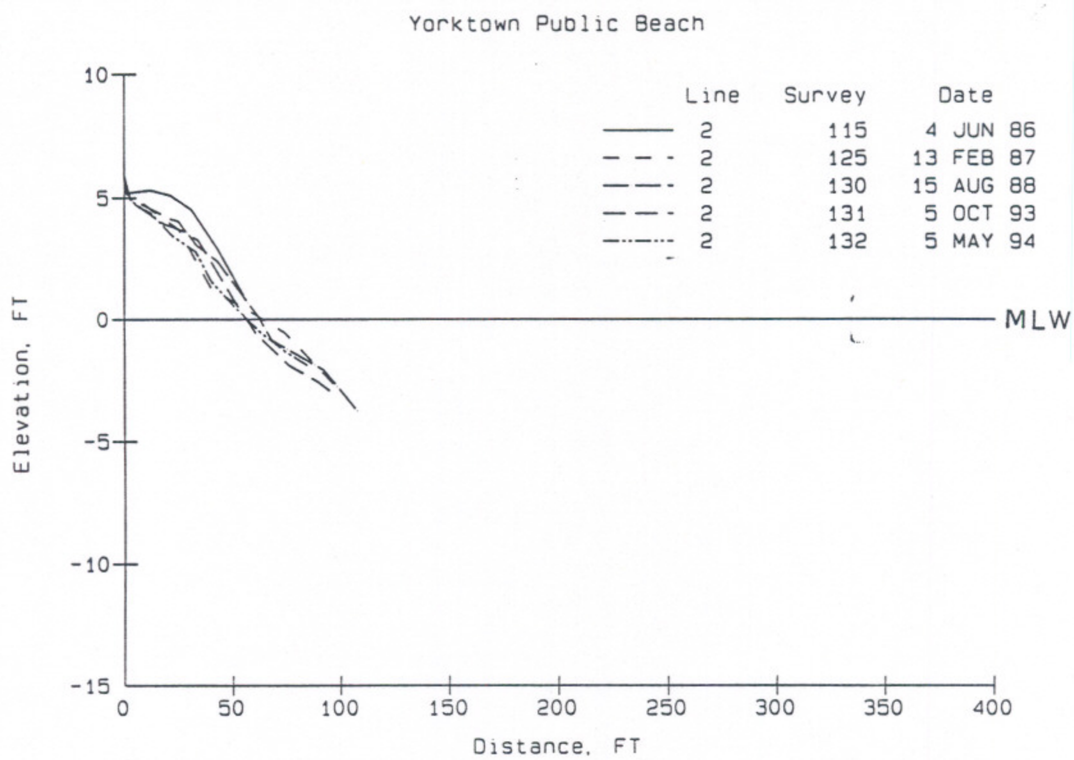
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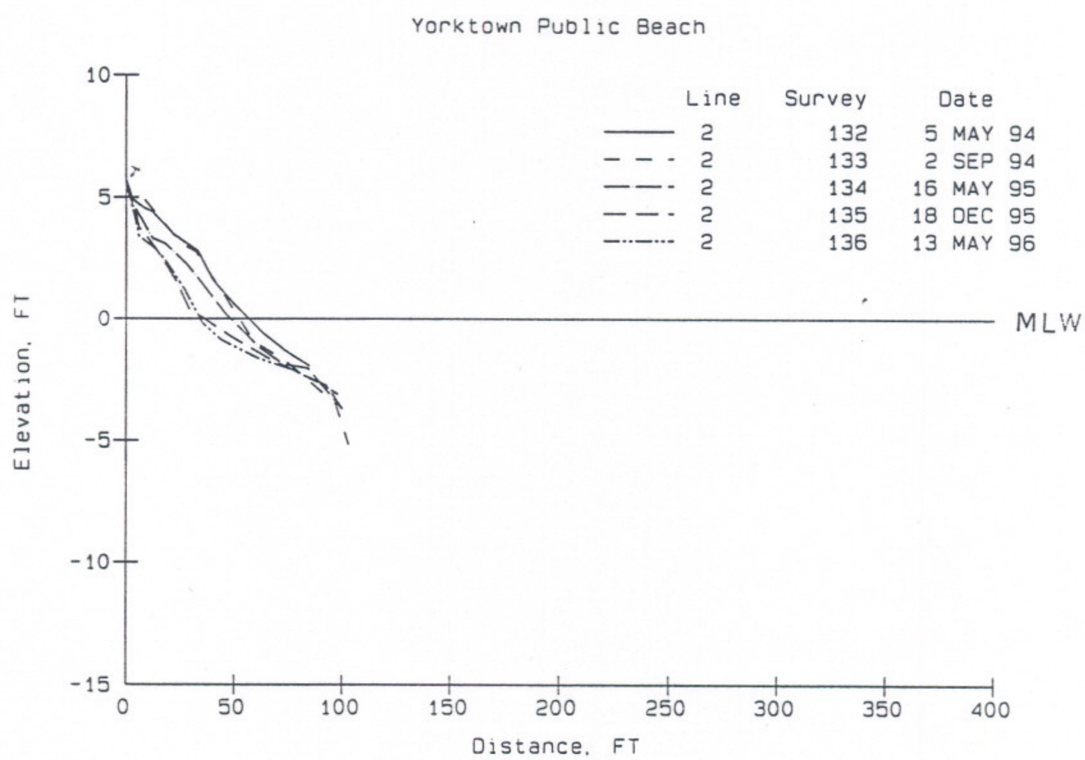
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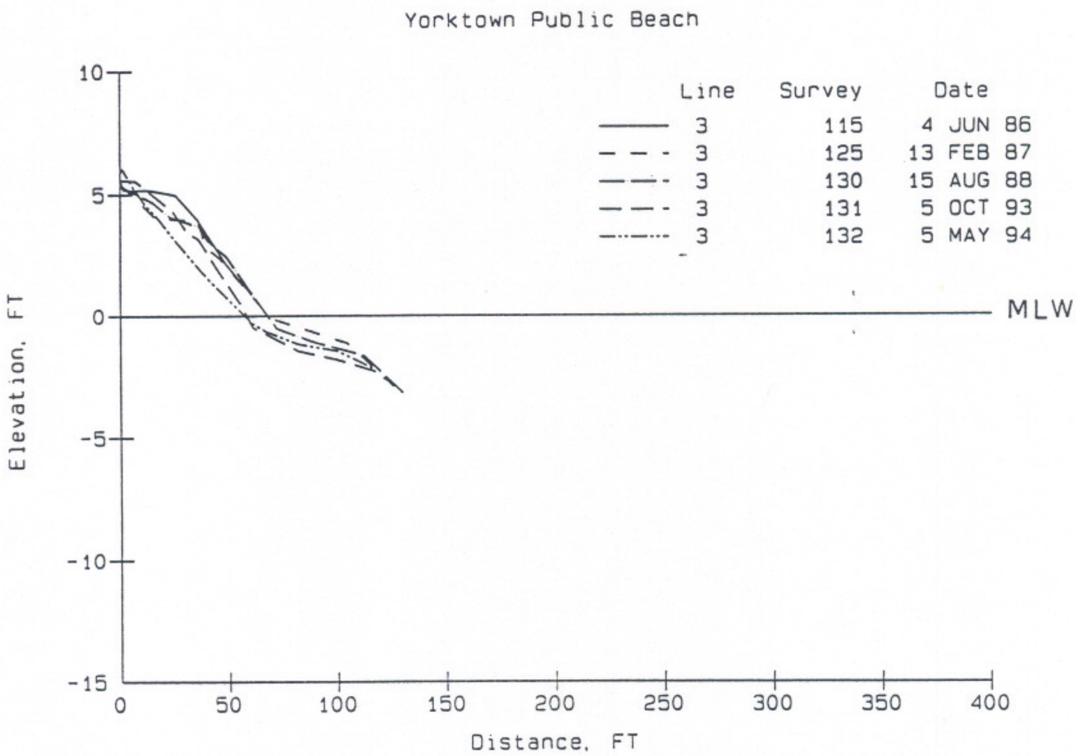
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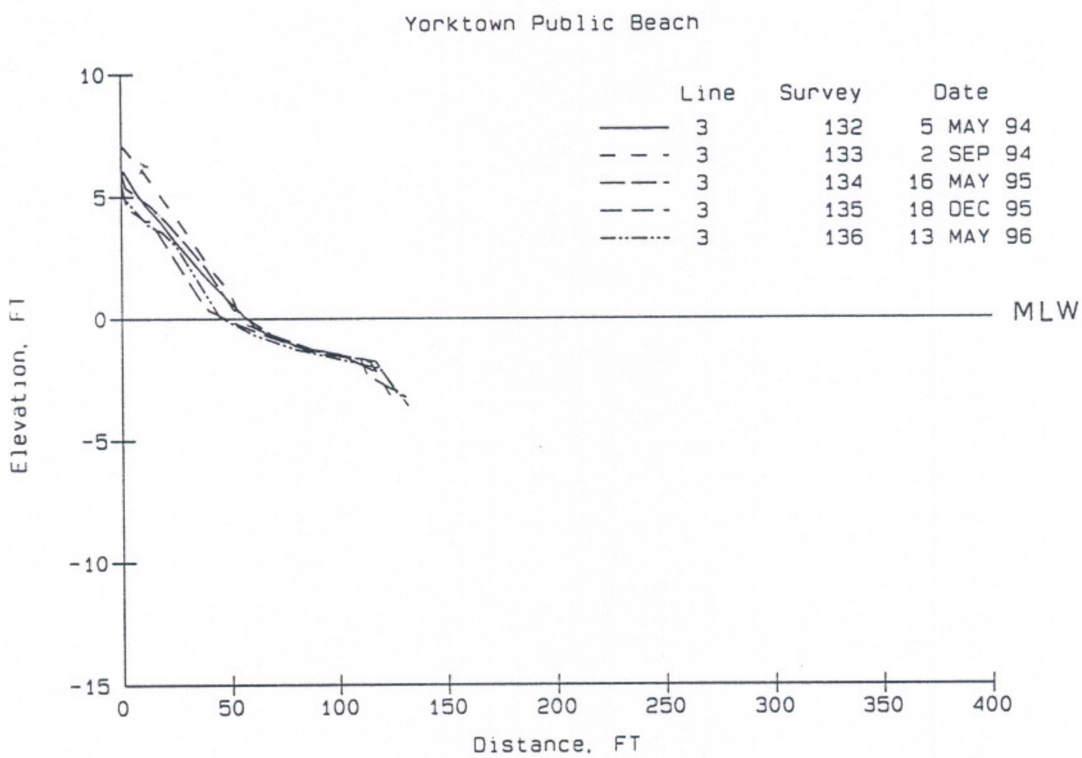
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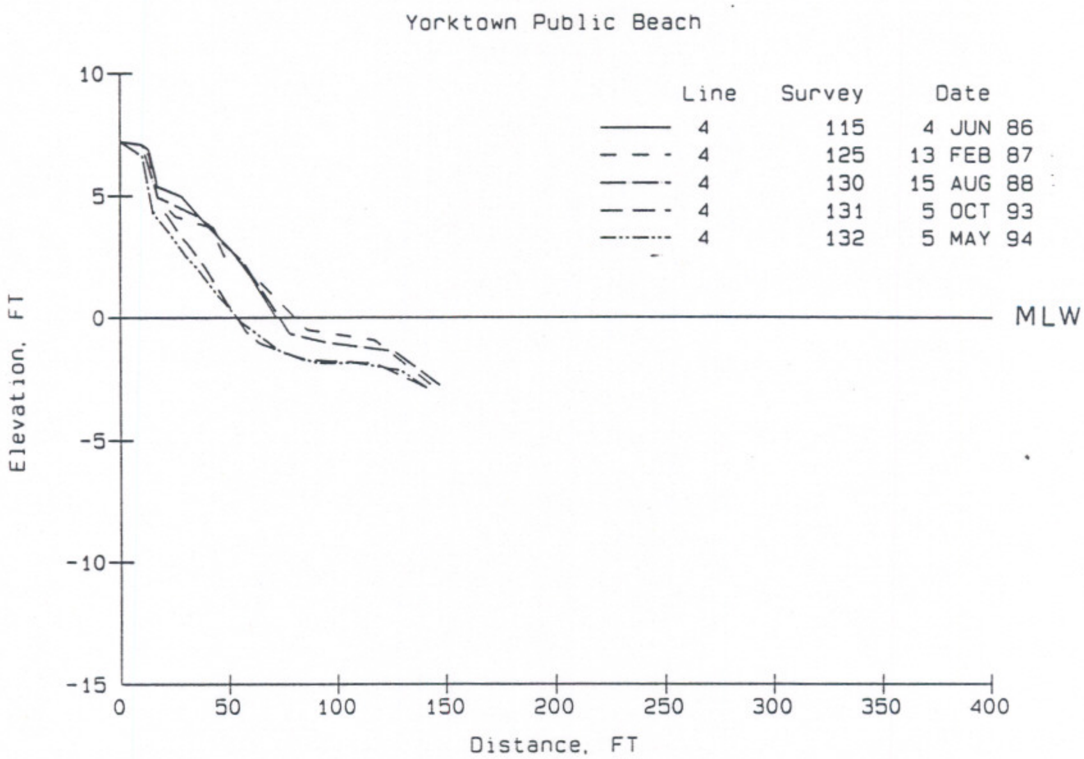
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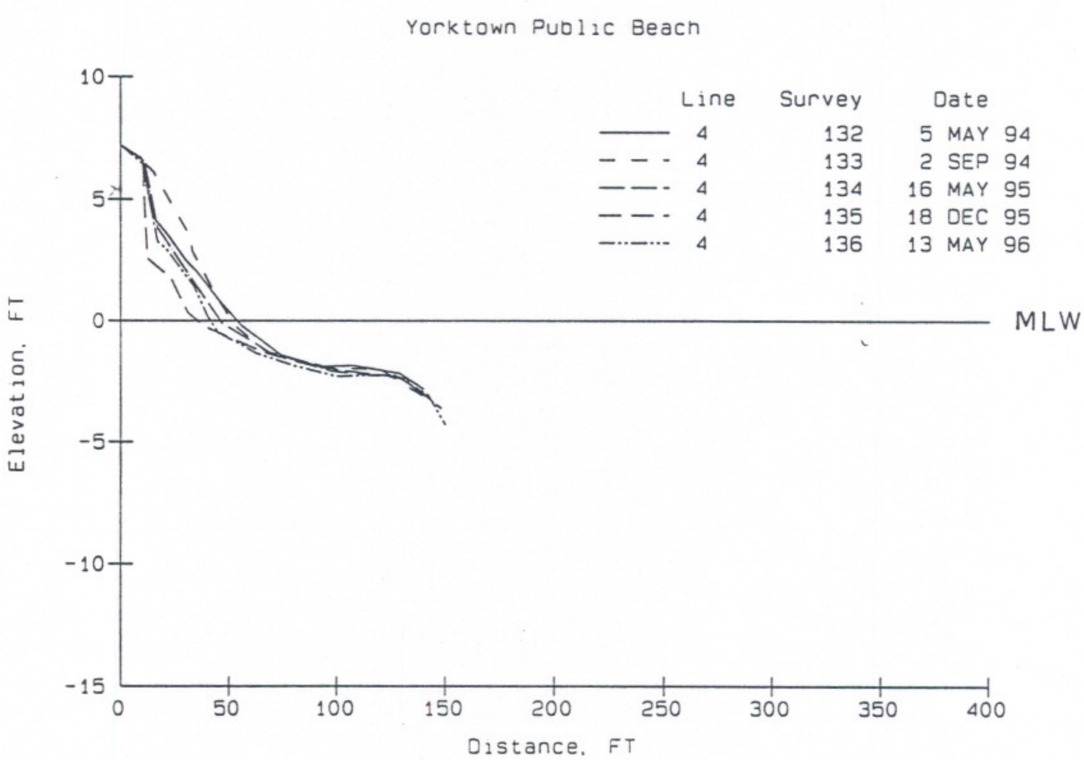
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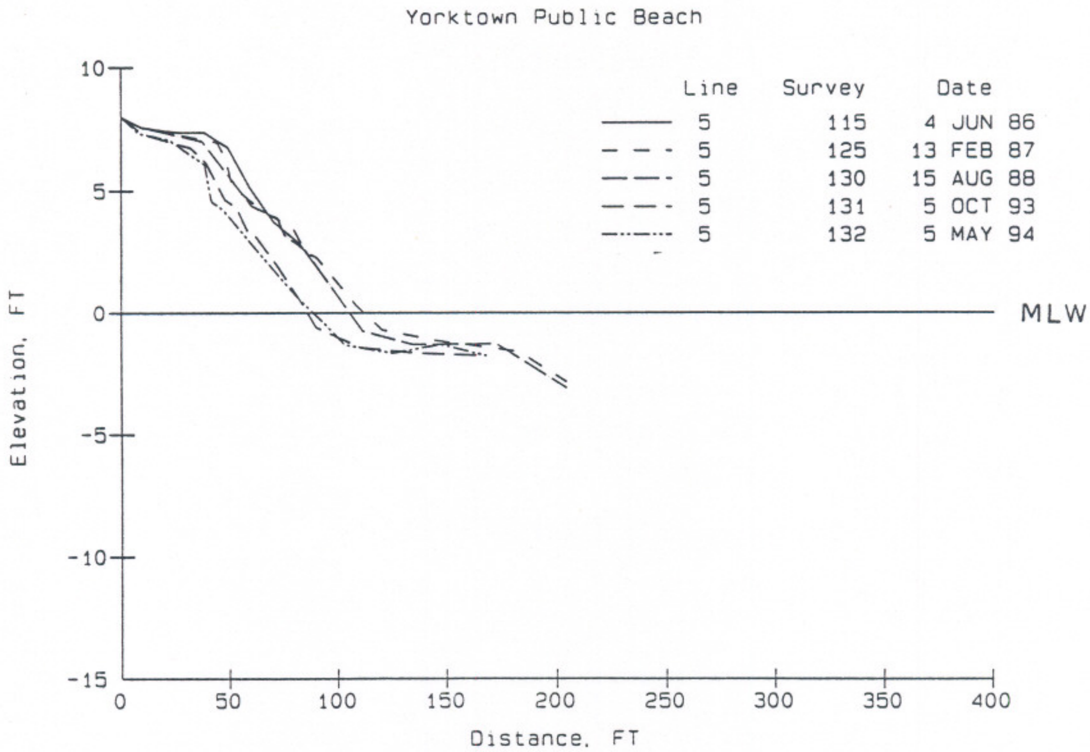
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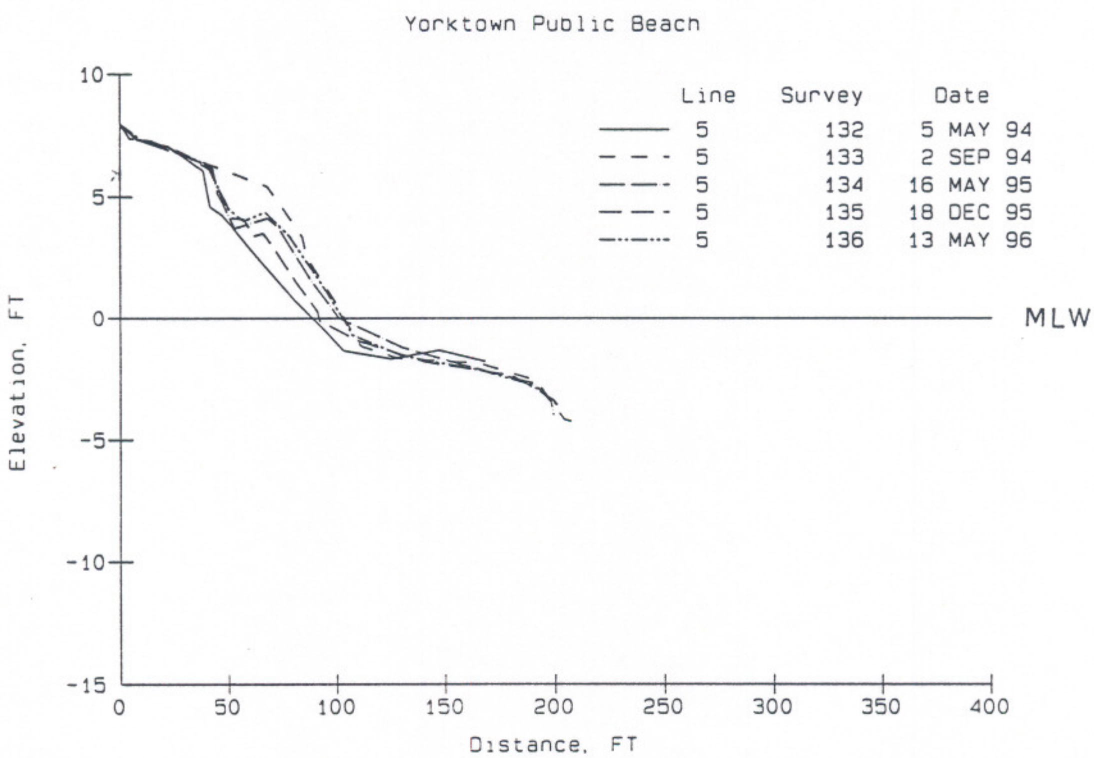
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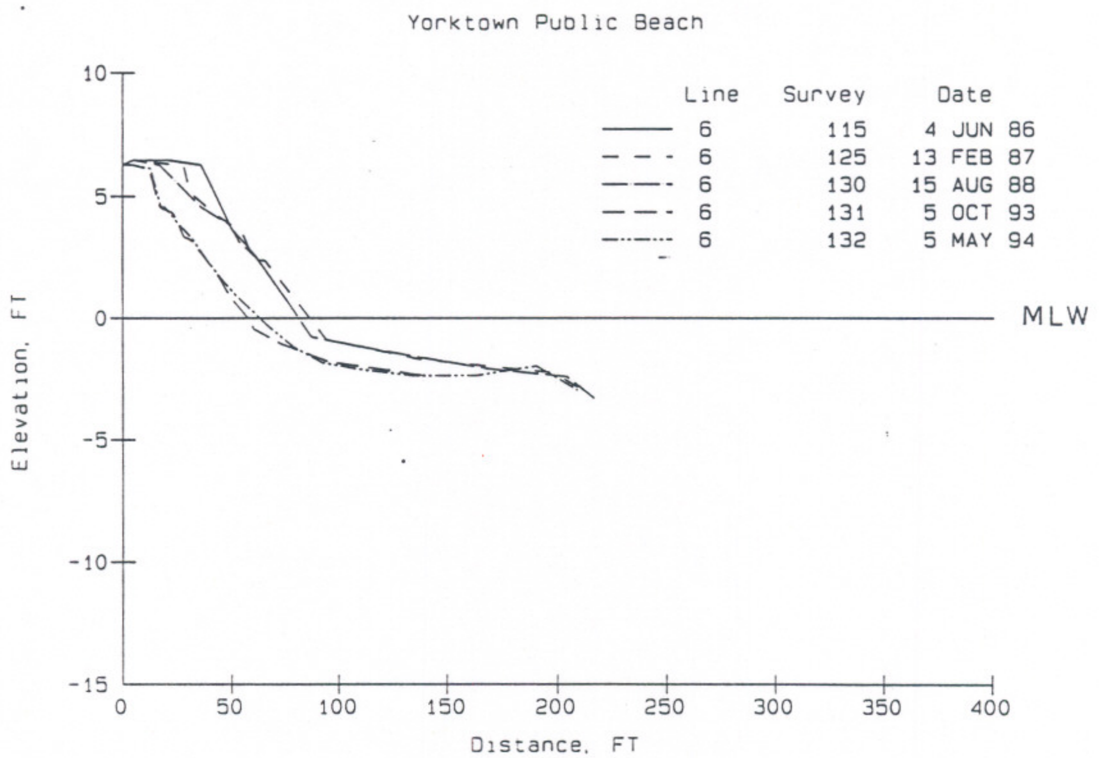
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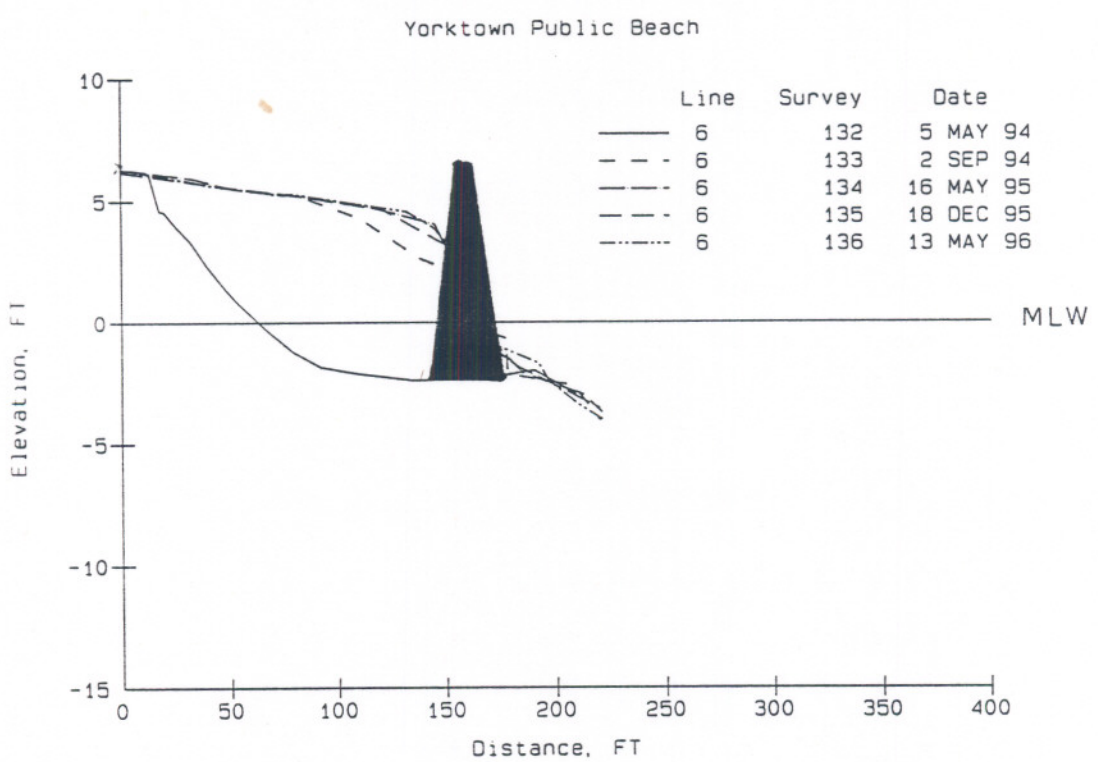
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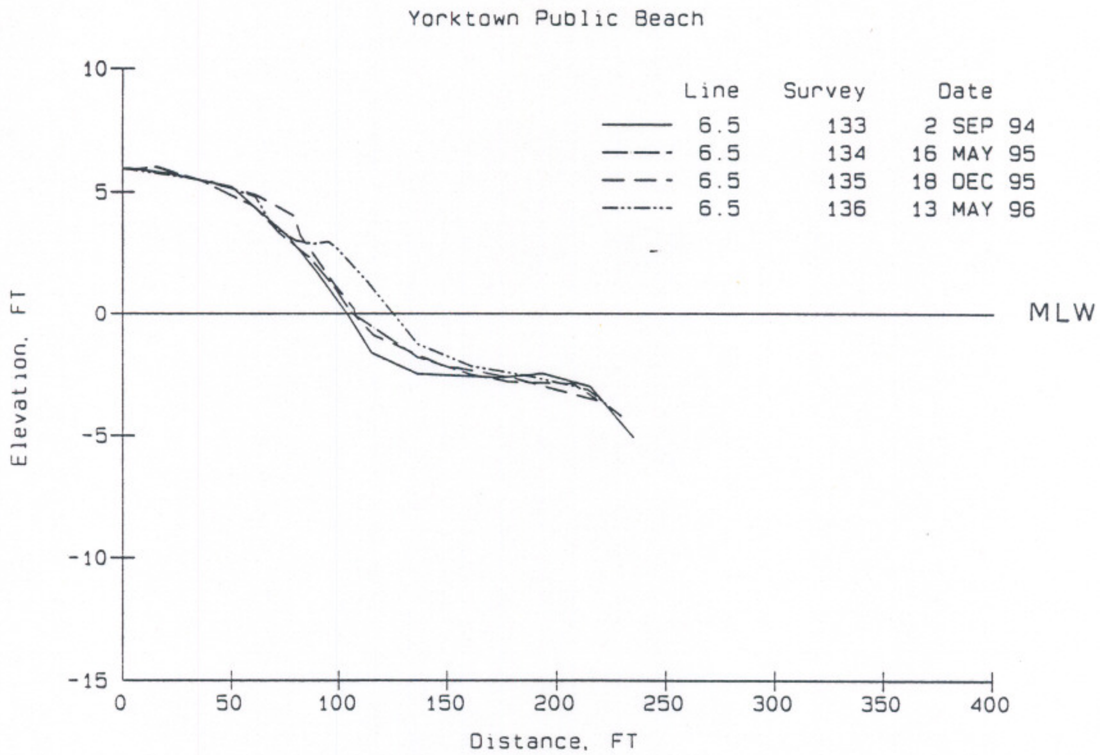

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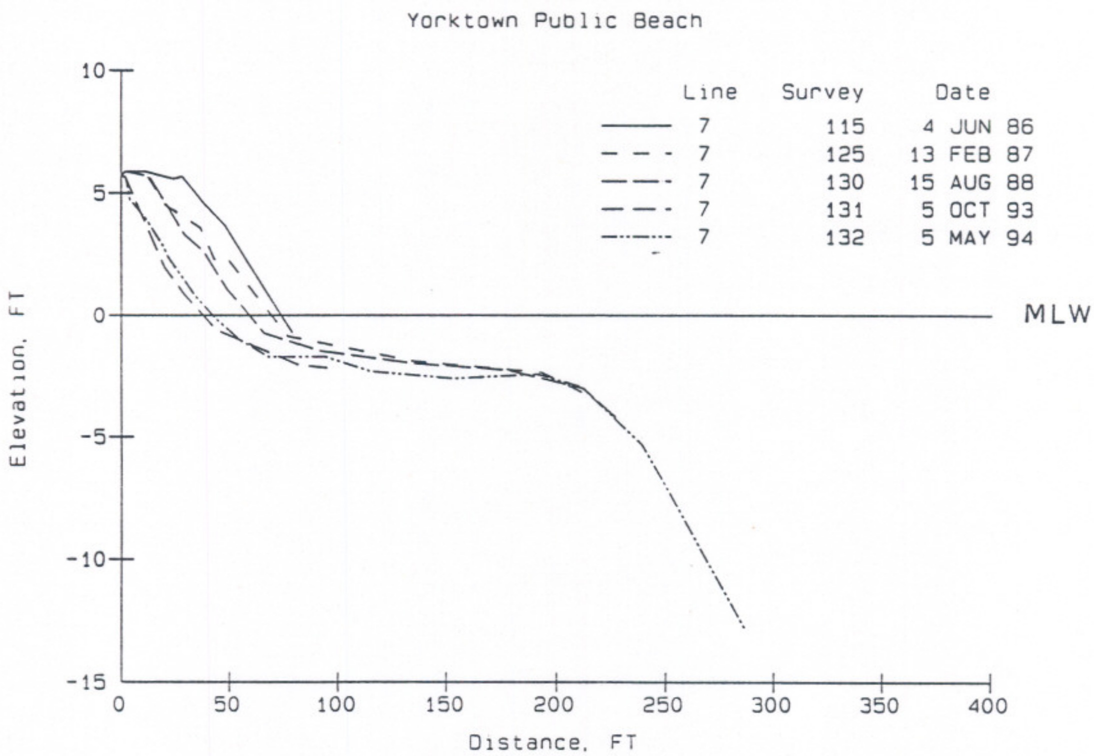
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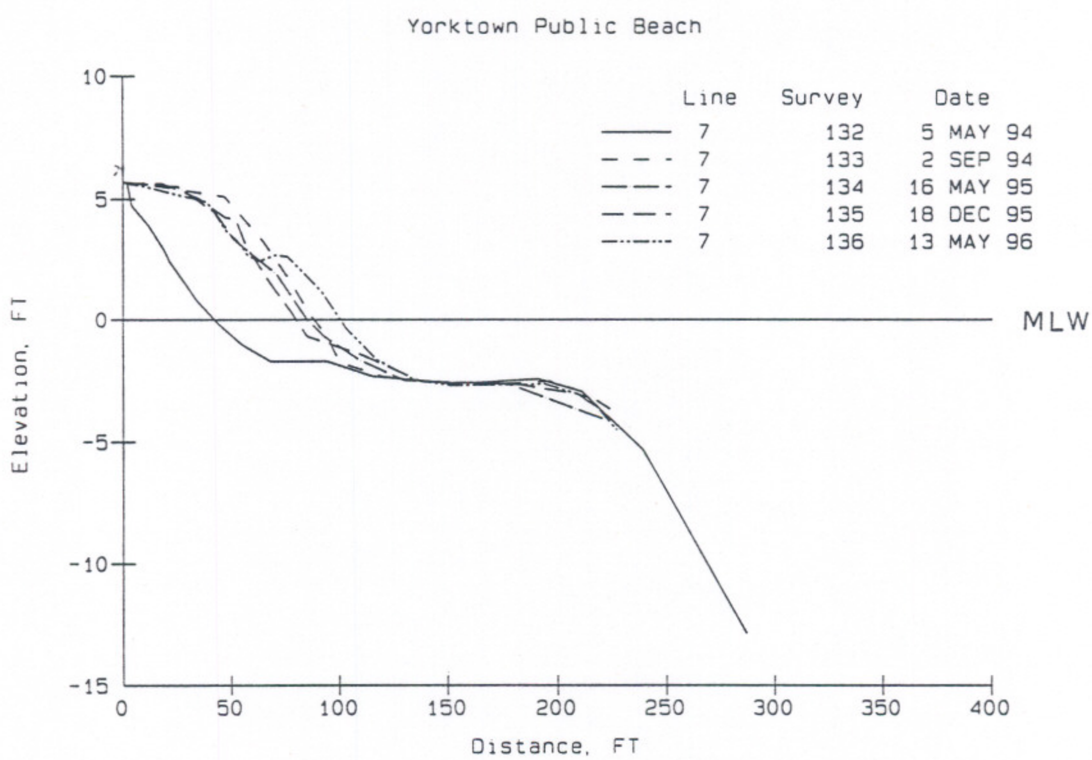
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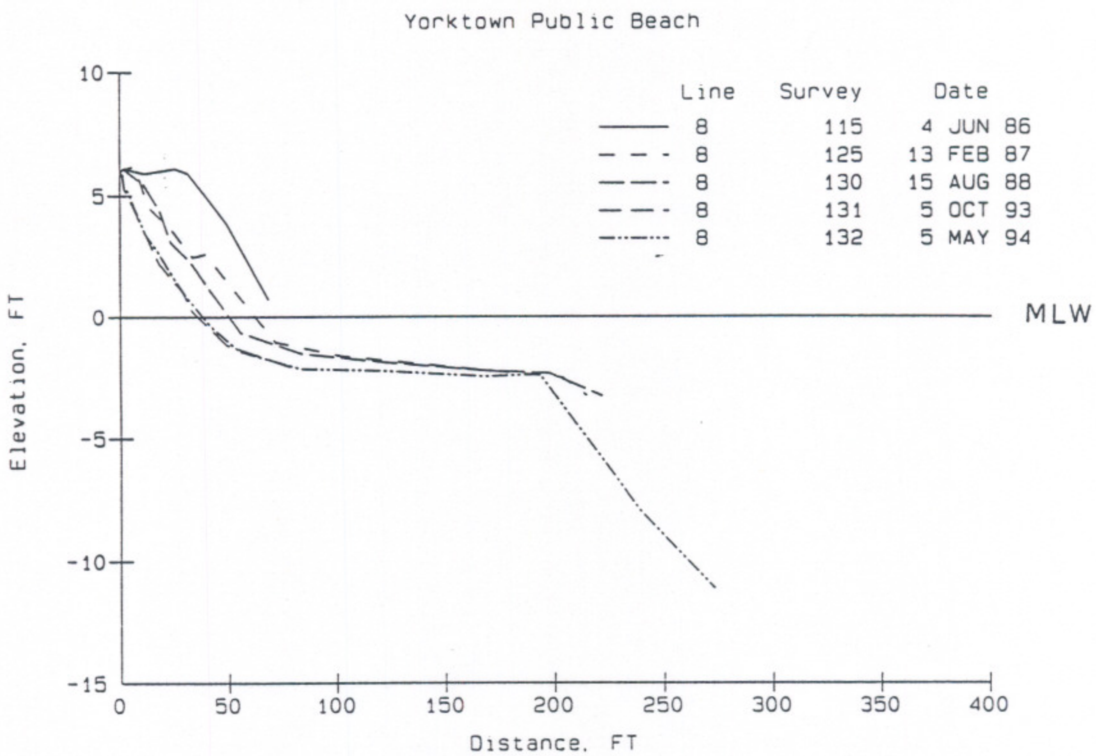
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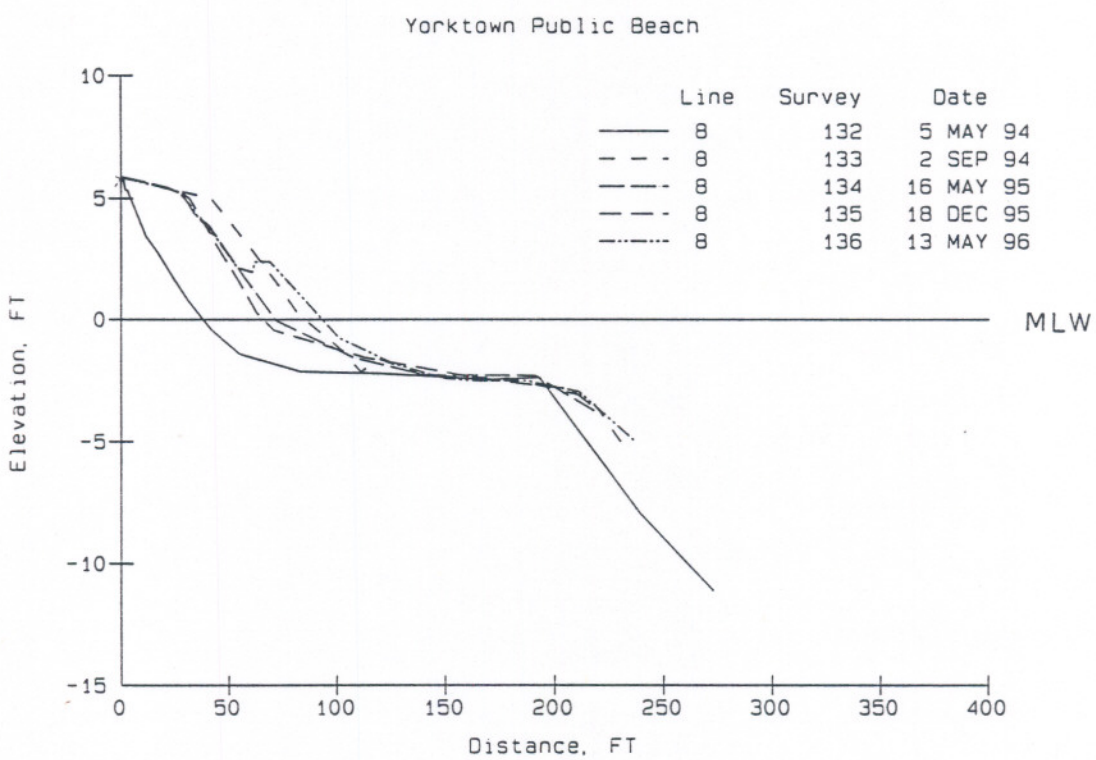
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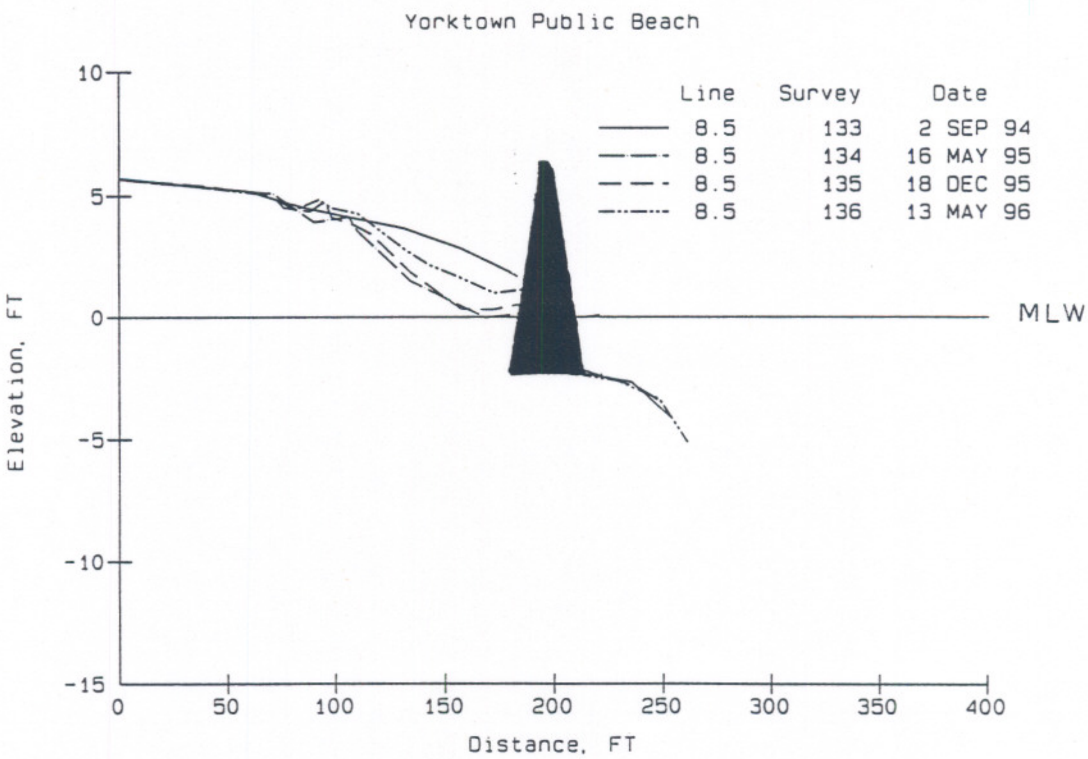
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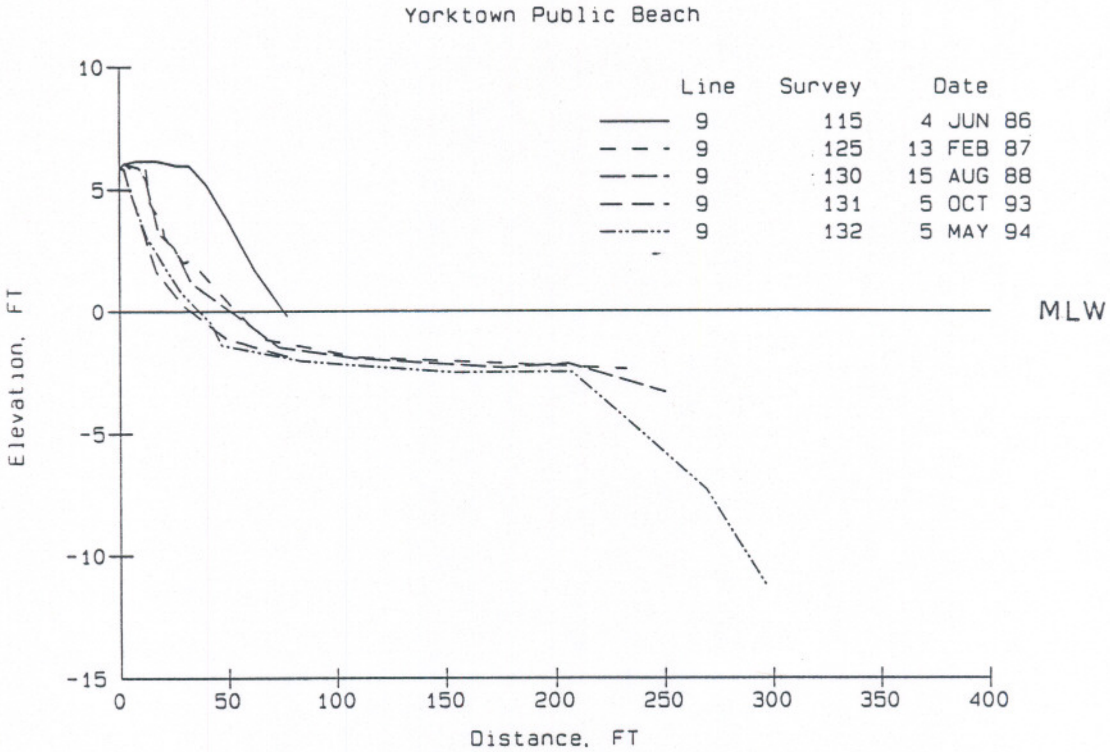
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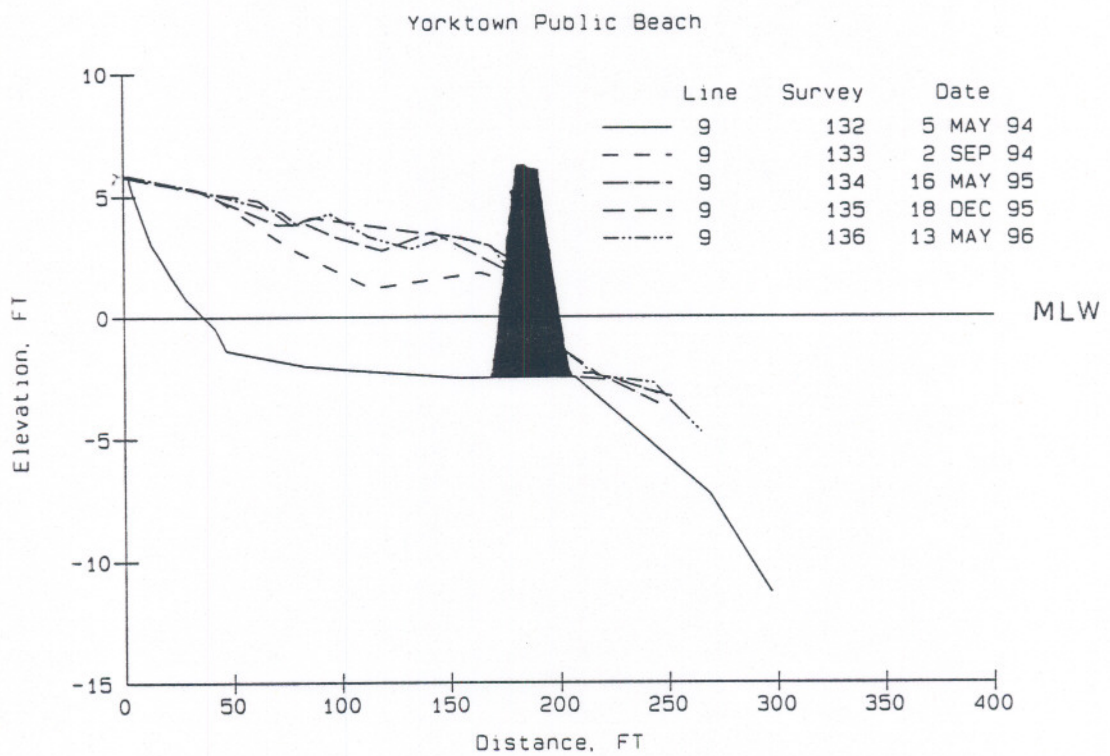
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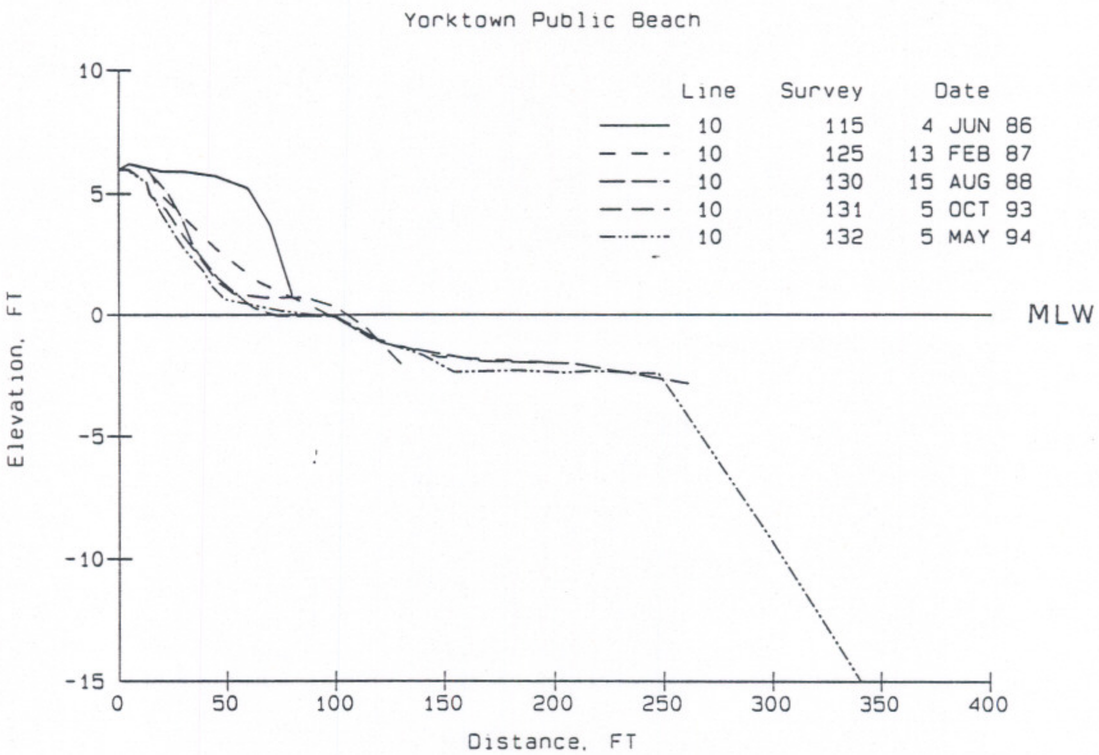
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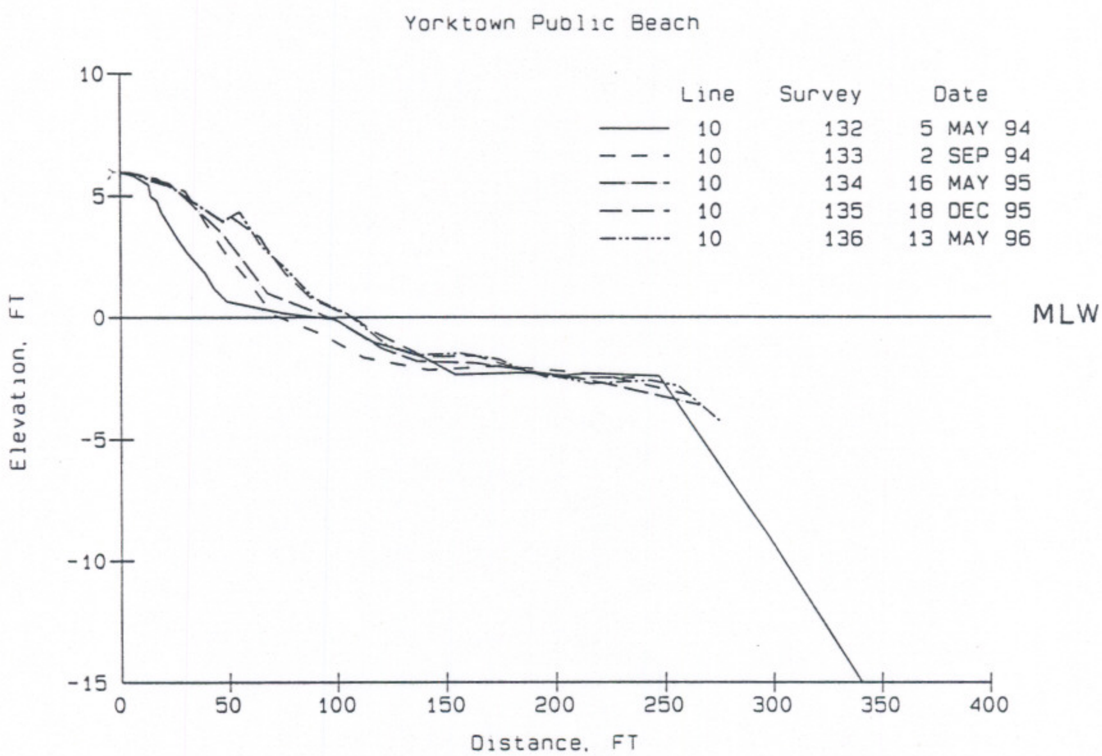
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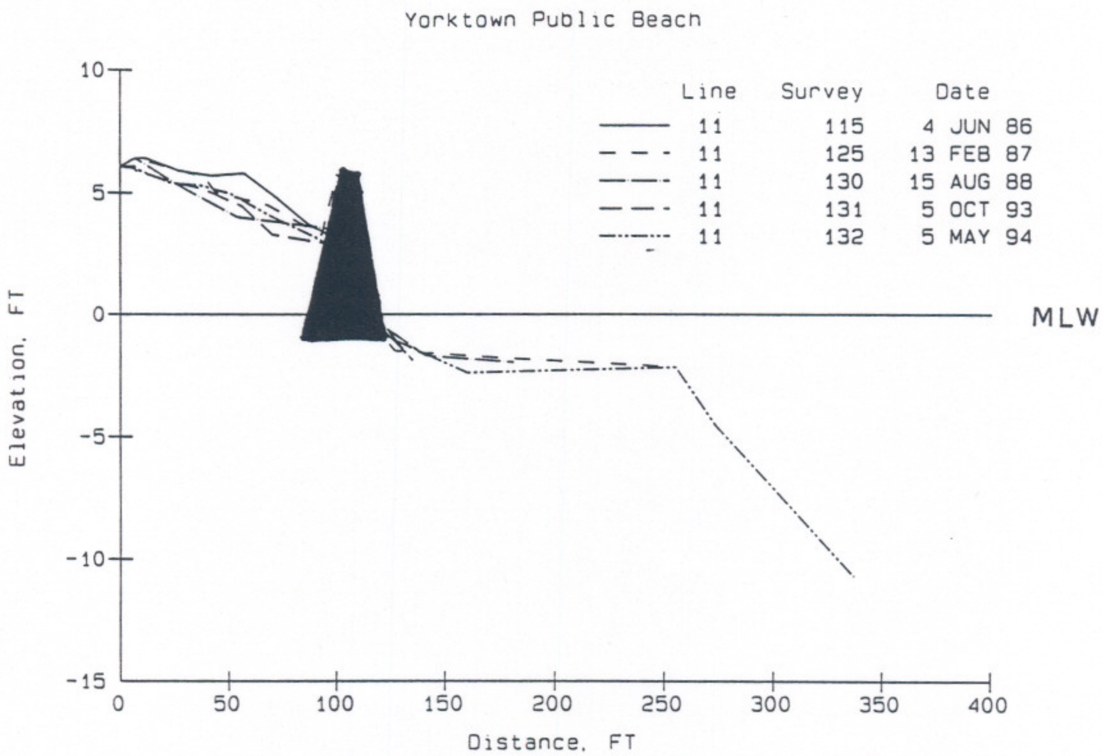

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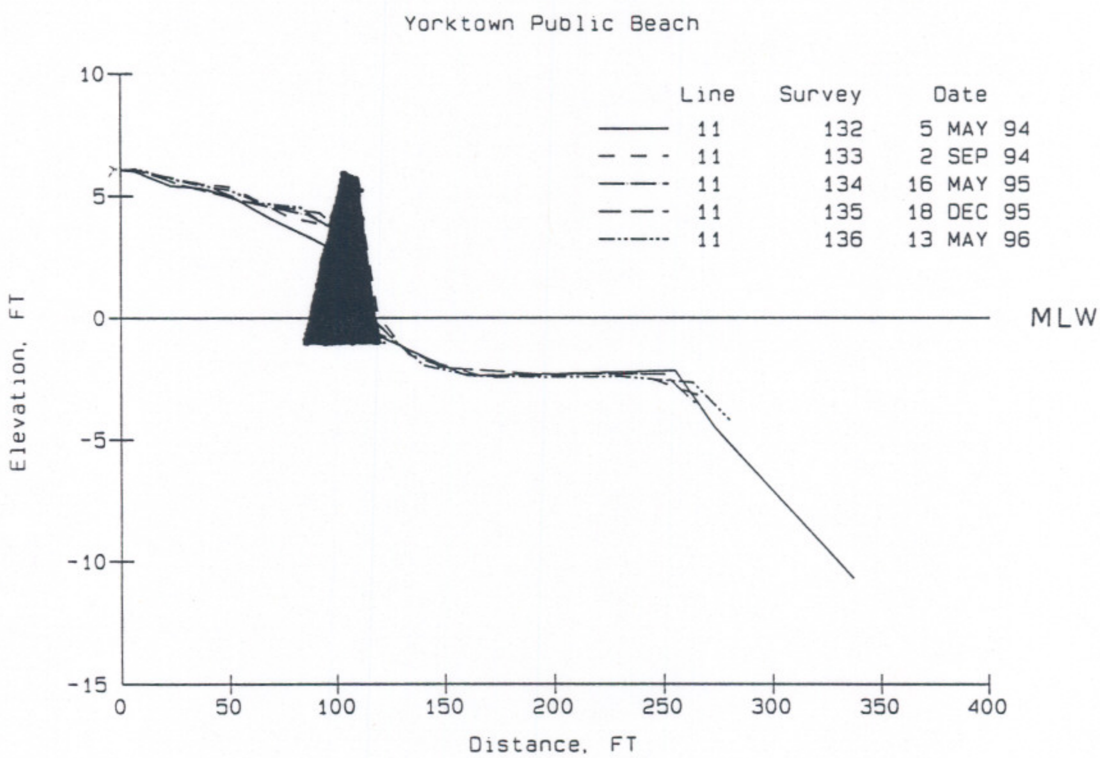

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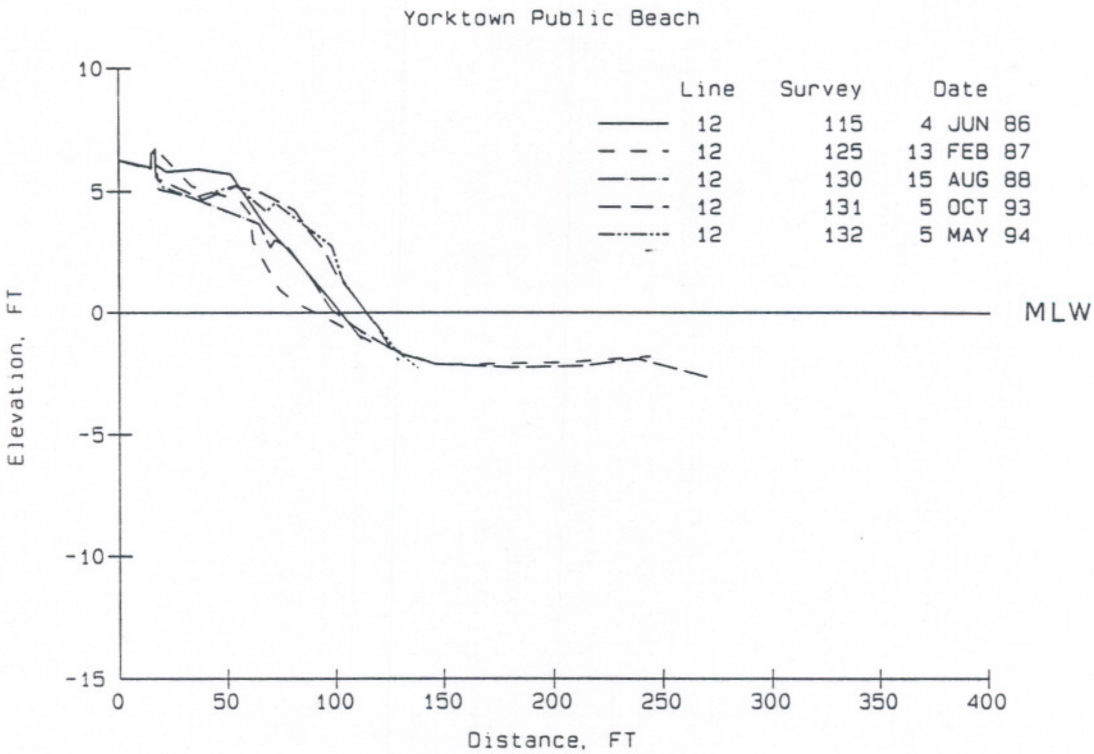
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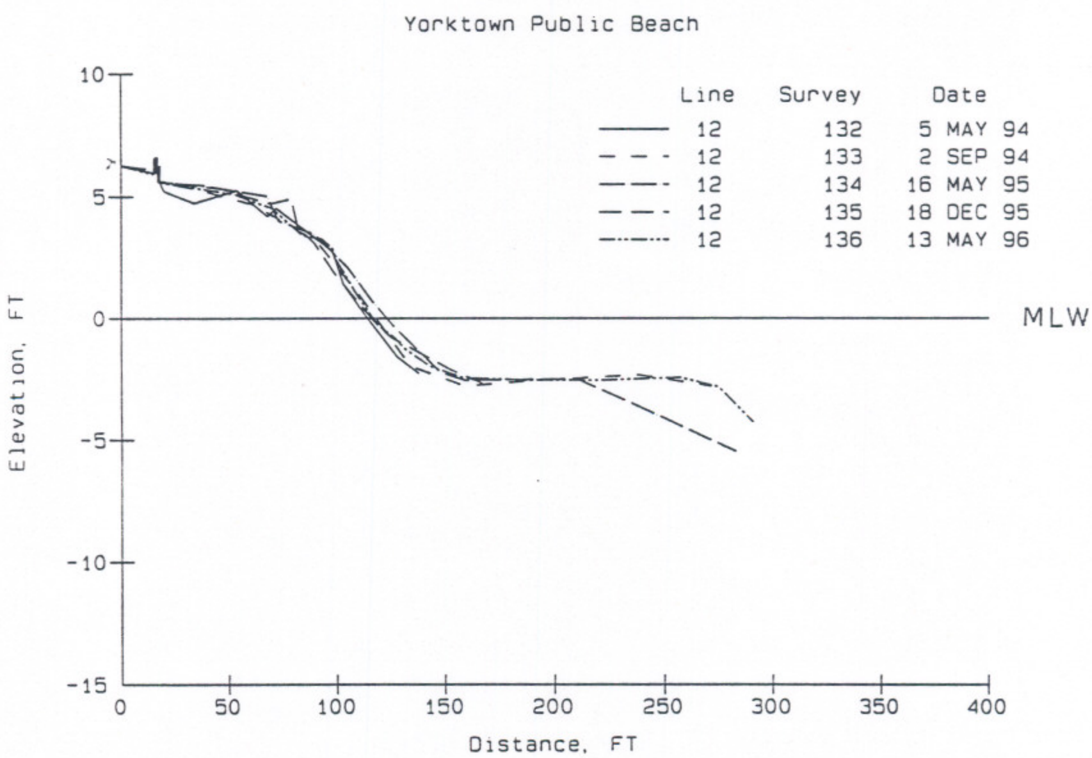
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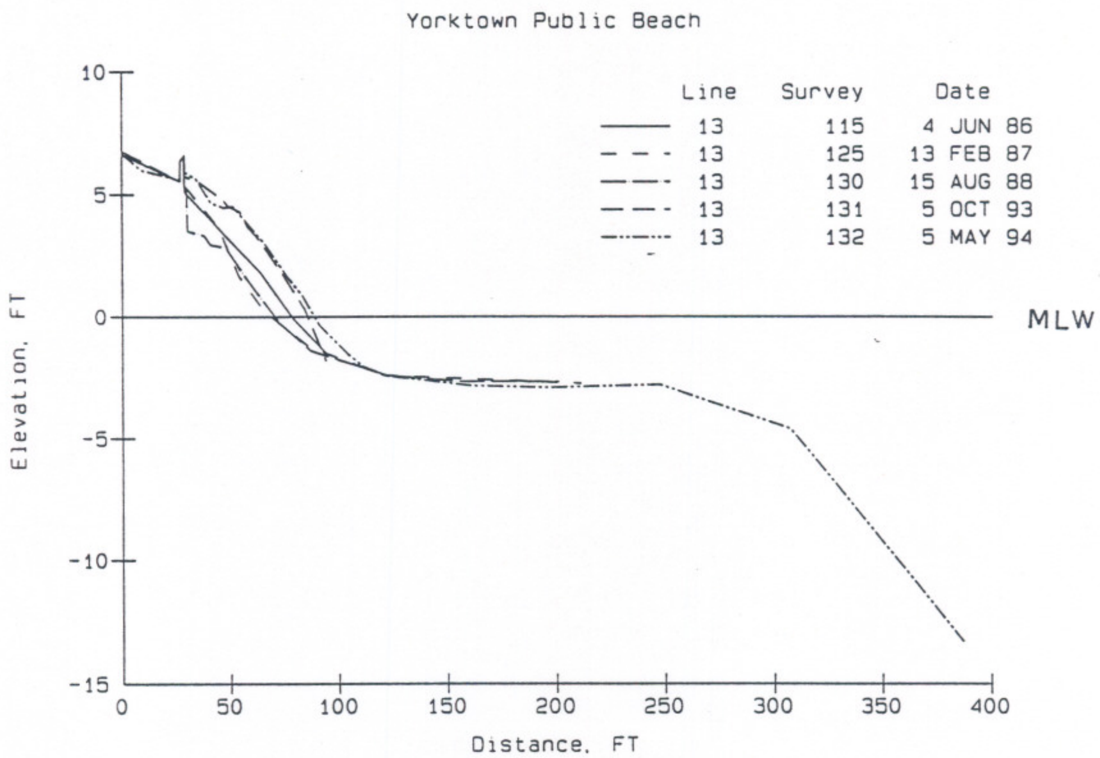
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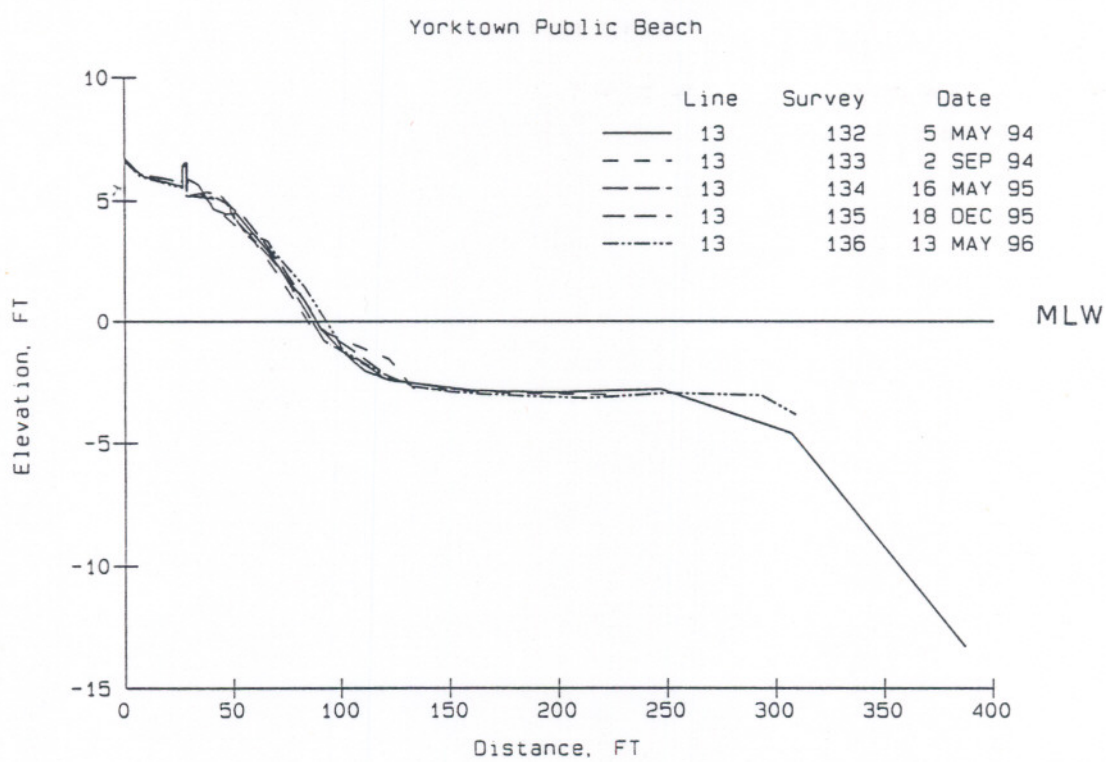
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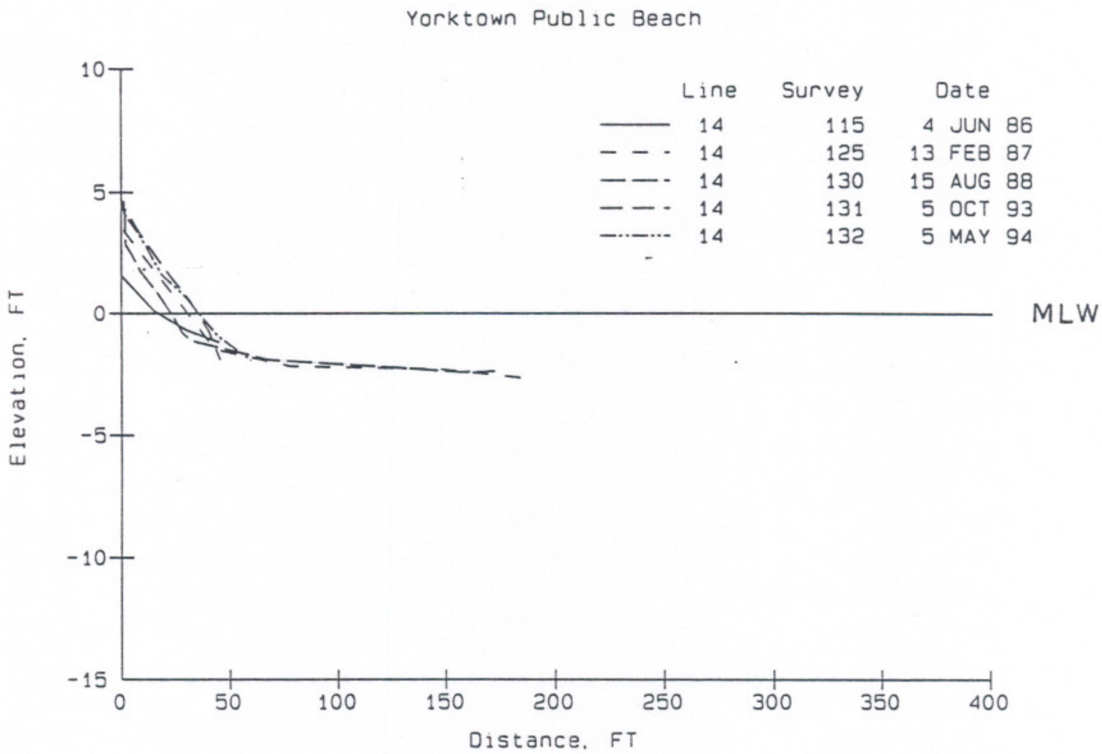
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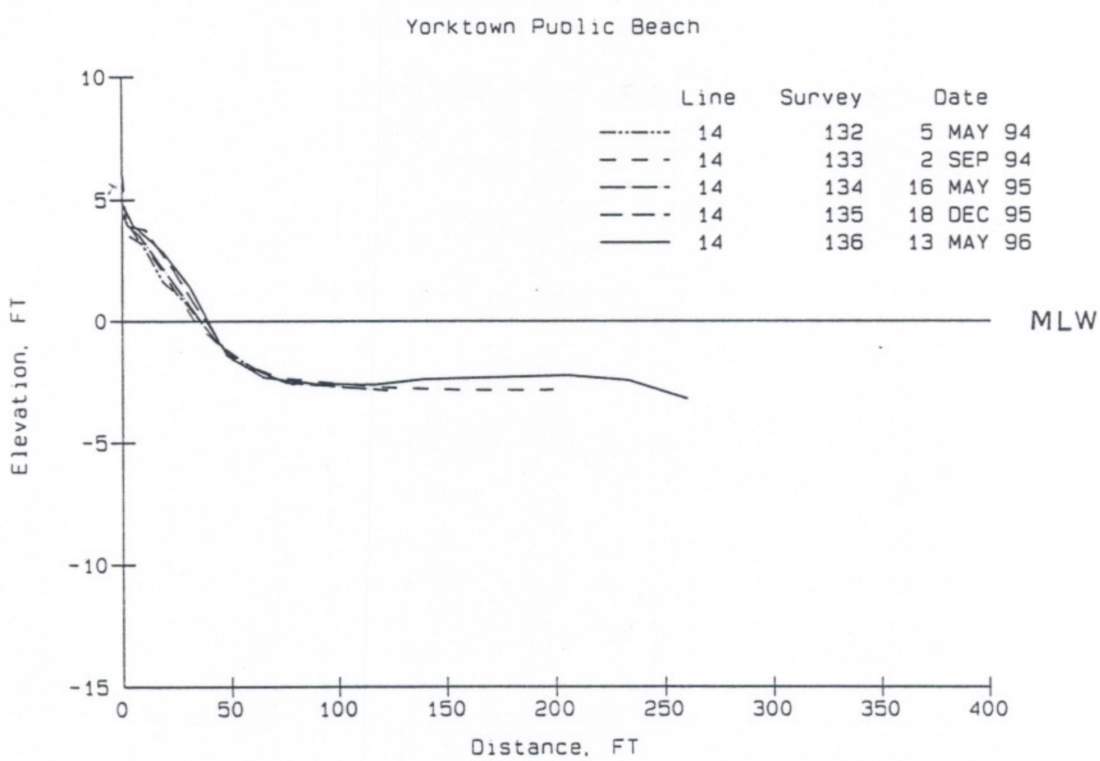
Yorktown Public Beach
Line Survey Date
14 132 5 MAY 94
14 133 2 SEP 94
14 134 16 MAY 95
14 135 18 DEC 95
14 136 13 MAY 96
MLW
Elevation, FT
Distance, FT
10
5
0
-5
-10
-15
0
50
100
150
200
250
300
350
400